Address 100 Barr Harbor Drive
PO Box C700
W. Conshohocken, PA
19428-2959 | USA

Phone 610.832.9500
Fax 610.832.9666
Web www.astm.org

Committee D02 on PETROLEUM PRODUCTS AND LUBRICANTS

Originally Issued: September 22, 2010

Reply to: Jeff Clark
Test Monitoring Center
6555 Penn Avenue
Pittsburgh, PA 15206
412-365-1032
jac@astmtmc.cmu.edu

Unapproved Minutes of the September 21, 2010 Cummins Test Surveillance Panel Meeting Paulsboro, NJ

The meeting was called to order at 8:50 am by Chairman Jim Moritz. The agenda is shown as **Attachment 1**. The attendance is show in **Attachment 2**. No membership changes were announced.

Meeting Minutes

The minutes of previous meetings were approved without objection (Clark, Fetterman).

ISM Merit System Change to Account for Industry Correction Factor

The report from the statisticians group, prepared by Phil Scinto of Lubrizol, is shown in **Attachment 3**. Method T2 from the presentation was the recommendation made by the stats group. Pat Fetterman stated that the pass fail limits for the ISM were set on the first ten tests (with three tests uncorrected for IAS) and that the method draws back to the first seven tests.

Following some discussion, Pat Fetterman and Steve Kennedy presented a Revised IAS Merit Calculation Proposal (**Attachment 4**). Further discussion ensued, after which Shawn Whitacre moved acceptance of the T2 Method effective for all test starts on or after September 27, 2010 (page 3 of Attachment 3 from the stats group report); Jim Matasic second. The motion failed 2-3-5. Unless other proposals are brought forward, this issue will remain at status quo.

Develop LTMSv2 for ISM and ISB

Jim Rutherford opened the discussion of LTMS Version 2 for the ISM by reviewing the LTMS Second Edition Draft 17.7, which is **Attachment 5**. Jim then showed the 'what-if' scenarios to give the panel a feel for the new system. Art Andrews presented similar discussion for the ISB, **Attachments 6 and 7**. A long, iterative discussion regarding components of ISB LTMS v2 took place. The ISB discussion resulted in a first iteration of v2 components, included as **Attachment 8**. Jim Moritz tasked panel members with evaluating this draft. A comparison between the test method and v2 LTMS will also need to be done. The ISB work will continue on conference calls.

PC-9 Fuel

Jim Moritz reminded the panel that T-11 severity issues may be resolved by a tweak to the PC-9 fuel blending. Jim wanted to make sure the panel was aware of this and had a chance to discuss any concerns that ISM testing would be affected by the change to the fuel. Tom Wingfield noted two things: the fuel will be within the PC-9 spec, and the fuel will be more like the PC-9 fuel of five years ago. Tom presented (**Attachment 9**) sample (sanitized to protect intellectual property) graphs of fuel properties that changed over time and an executive summary and conclusion of his findings.

ISM OFDP

Jeff Clark presented some OFDP plots (**Attachment 10**) in response to concerns that there may be severity concerns (mild) with the new batch of ISM oil filters. The two most recent tests failed mild. The panel will continue discussion as events merits.

The meeting adjourned at 5:15 p.m.

Attachment 1

Cummins Surveillance Panel

Proposed Meeting Agenda
September 21, 2010
8:30 am – 5:00 pm
ExxonMobil Research and Development

1) Chairman's Comments	**Jim Moritz**
2) Membership / Attendance	**Jeff Clark**
3) Approval of Minutes of last Meeting	**Jeff Clark**
4) ISM Merit System Change to Account for ICF	**Group**
5) Develop LTMSv2 of ISB and ISM	**Group**
6) Old Business	**Jim Moritz**
7) New Business / A.O.B.	**Jim Moritz**
8) Next Meeting	**Jim Moritz**

Attachment 2

Cummins SP Meeting Attendance
Paulsboro, NJ
September 21, 2010

Name	Company
Jim Moritz	Intertek
Jim Gutzwiller	Infineum
Zack Bishop	TEI
Jim Matasic	Lubrizol
Mark Cooper	ChevronOronite
Doyle Boese	Infineum
Tom Wingfield	ChevronPhillips
Chris Castanien	Lubrizol
Jim Rutherford	ChevronOronite
Jim McCord	SwRI
Jeff Clark	TMC
Mike Alessi	ExxonMobil
Shawn Whitacre	Cummins
Pat Fetterman	Infineum
Ryan Johnson	SwRI
Riccardo Conti	ExxonMobil
Art Andrews	ExxonMobil
Bob Campbell	Afton
Todd Dvorak	Afton
Jim Carter	Haltermann
Steve Kennedy	ExxonMobil
Andy Ritchie	Infineum

Joined Meeting Via Conference Call

Scott Richards	SwRI
Jason Bowden	OHT

Attachment 3

ISM IAS Merit Calculations and Industry Correction Factors

August 2, 2010

Objectives/Direction from SP

- Find a Correction Factor, Transformation and/or Change in the Merit System for ISM IAS that:
  - Allows for full merits to be achieved for IAS weight loss
  - Does Not Change the Test from its Historical and Current State
    - Is as transparent as possible to when targets for this test were set
    - Does not affect test severity, as measured by reference testing
    - Does not significantly affect test/merit variability

Executive Summary

- Half a Dozen Proposals were Reviewed and Evaluated by the Statistics Task Force
- The Method that Best Satisfies the SP Objectives is Called MeritsT2 and Involves Using a Transformation
- The Method is Minimally Invasive
  - IAS Results of 7.4 and Greater Use the Current Correction Factor of +19.1
  - For IAS Results below 7.4
    - Corrected IAS = $\{(IAS)^{(0.8)} + 8.8\}^{(1.25)}$

Executive Summary

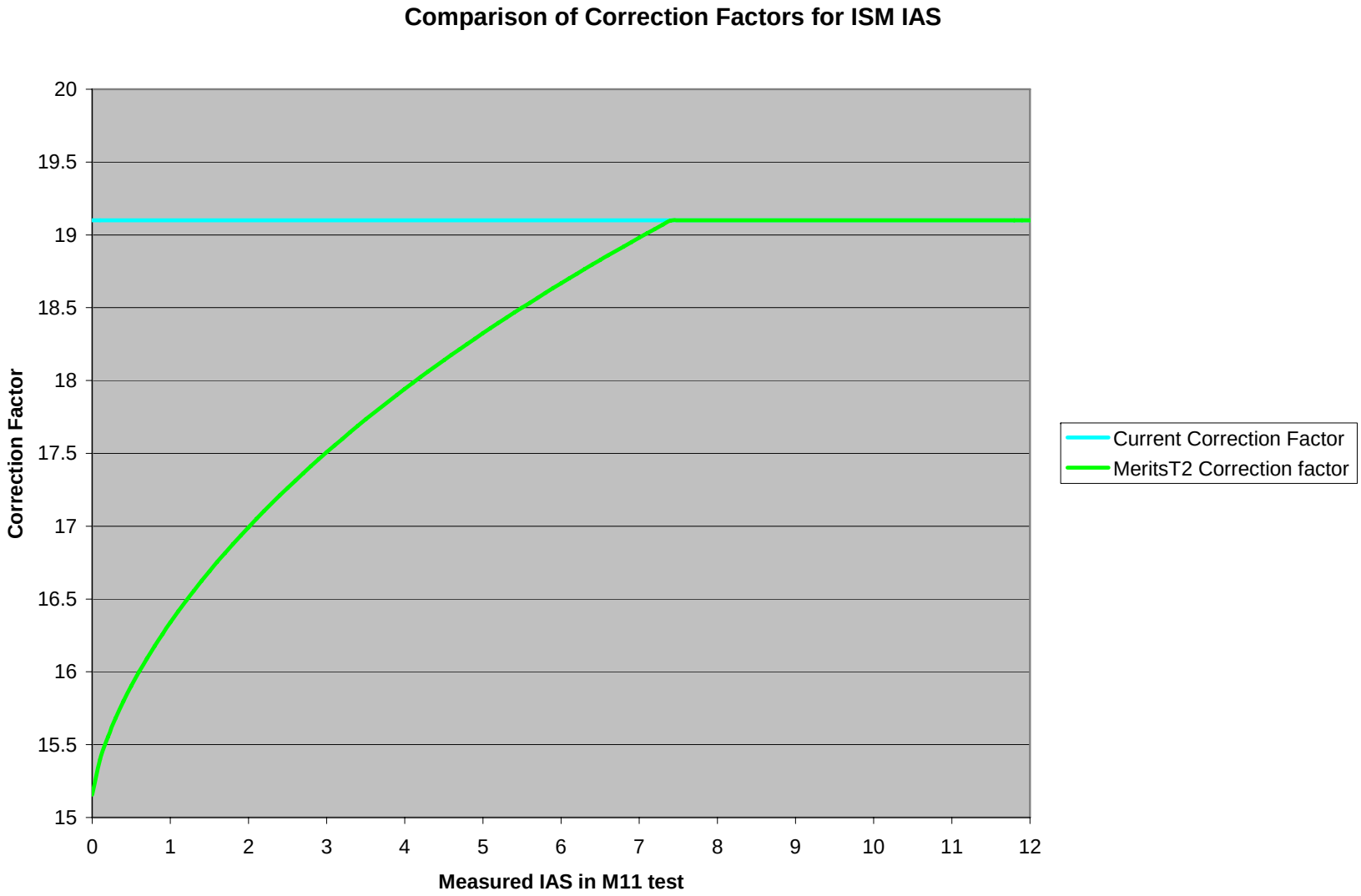
- MeritsT2 has Minimal Impact on Changing the Test
- MeritsT2 Uses Current Min, Max and Anchor
- MeritsT2 is no Different than Current Correction of +19.1 for IAS Test Results Greater than or Equal to 7.4
- MeritsT2 Allows IAS Test Results Below 0.4 to Achieve Full Merits
- MeritsT2 Gives More Merits to IAS Test Results Below 7.4 than Current Correction
  - MeritsT2 is “Good” for Oils that are Below the Anchor

How to Apply Correction Factor

- For Uncorrected IAS < 7.4
  - Corrected IAS = $\{(IAS)^{(0.8)} + 8.8\}^{(1.25)}$
- For Uncorrected IAS >= 7.4
  - Corrected IAS = IAS + 19.1

ISM IAS	MeritsT2 Correction Factor	MeritsT2 Corrected IAS	Current Correction Factor	Current Corrected IAS
0	15.15665413	15.2	19.1	19.1
1	16.33934128	17.3	19.1	20.1
2	16.99360818	19.0	19.1	21.1
3	17.50789266	20.5	19.1	22.1
4	17.94303481	21.9	19.1	23.1
5	18.32503802	23.3	19.1	24.1
6	18.66807386	24.7	19.1	25.1
7	18.98092906	26.0	19.1	26.1
8	19.1	27.1	19.1	27.1
9	19.1	28.1	19.1	28.1

Plots of Correction Factors



Why Cap of 19.1 in MeritsT2?

- Better Maintains Current Severity of Test for Candidate Oils Above the Anchor
- Essentially Only Changes from Current Industry Correction Factor Practice for Test Results Below 7.4

Implications of CFs on IAS 830-2

- Minimal
  - See 830-2 Results, On Right
  - BUT, Must Check Merits

IAS Corrected Result	MeritsT2 Corrected IAS
19.4	19.4
35.5	35.5
33.3	33.3
25.9	25.9
26.2	26.2
29.2	29.2
40.4	40.4
36.7	36.7
28.4	28.4
27.6	27.6
26.4	26.4
32.3	32.3
39.1	39.1
36.9	36.9
28.5	28.5
24.1	23.3
30.2	30.2
27.1	27.1
22.4	20.9
24.6	24
24.7	24.1
33.7	33.7
27.4	27.4
26.1	26
34	34
31.6	31.6
23.9	23.1
34.1	34.1
37.1	37.1
23.1	21.9
33.6	33.6
24.6	24
24.7	24.1
23.8	22.9
30.6	30.6
21.6	19.8
26.3	26.2
28.9	28.9
29.8	29.8
29.2	29.2

Data Analysis of Merits

- 40 Reference Test Results on RO 830-2
- Summary of Statistical Tests in Appendix
- Calculate and Compare Means and Standard Deviations of IAS Merits Since 2008 (Last 15 Tests)
  - Also Show First 7 Tests*
- 7 Merit Proposals Evaluated for IAS
  - Merits1: Current: **16/27/49**
  - Merits2: 23/27/49
  - Merits3: 22/31/43
  - Merits4: 20/27/49
  - Merits5: 22/31/49
  - MeritsT1: **16/27/49**, Transformation, No Cap
  - MeritsT2: **16/27/49**, Transformation, Cap of 19.1

Comparison of Different Proposals on RO 830-2

- MeritsT1 and MeritsT2 (and to some degree Merits4) Satisfy Objective of Allowing Maximum IAS Merits While Minimizing any Changes in the Test
  - Note that the means listed below are simple arithmetic averages and not Least-Square Means

Merit Proposal	N	Mean IAS Merits	StDev	Minimum	Maximum
Current	7*	324.1	147.6	136.8	591.8
Current	15	353.3	99.6	189.3	521.8
Merits2	15	423.1	181.6	189.3	700.0
Merits3	15	466.1	165.7	172.1	700.0
Merits4	15	378.7	130.8	189.3	620.0
Merits5	15	474.2	153.5	231.4	700.0
MeritsT1	15	355.1	127.3	152.7	579.1
MeritsT2	15	366.0	115.9	189.3	579.1

Summary for ISM IAS

- MeritsT1, MeritsT2 and Merits4 Satisfy Objectives
  - Merits4 is the Simplest, but has a Larger Standard Deviation than MeritsT1 and MeritsT2 and Changes the Severity of the Test More than MeritsT1 and MeritsT2
  - MeritsT1 is Best at Minimizing a Change in the Test for RO 830-2, But Gives a Slight Penalty to Oils Above the Anchor and has a Larger Standard Deviation than MeritsT2
  - MeritsT2 has Smallest Variability
  - MeritsT1 and MeritsT2 Give a Slight Reward to Oils Below the Anchor
- MeritsT2 is the Recommendation to the Surveillance Panel

Appendix

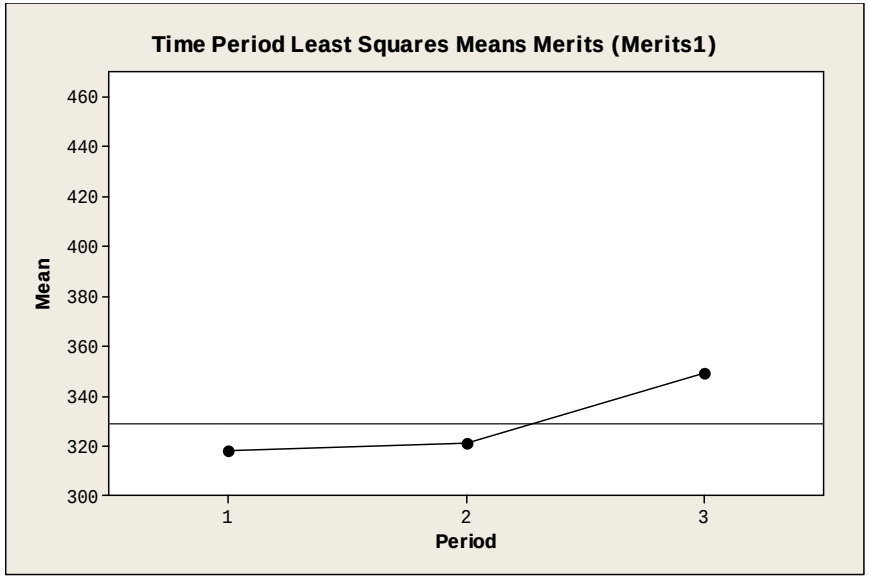
- Summary of Statistical Analysis

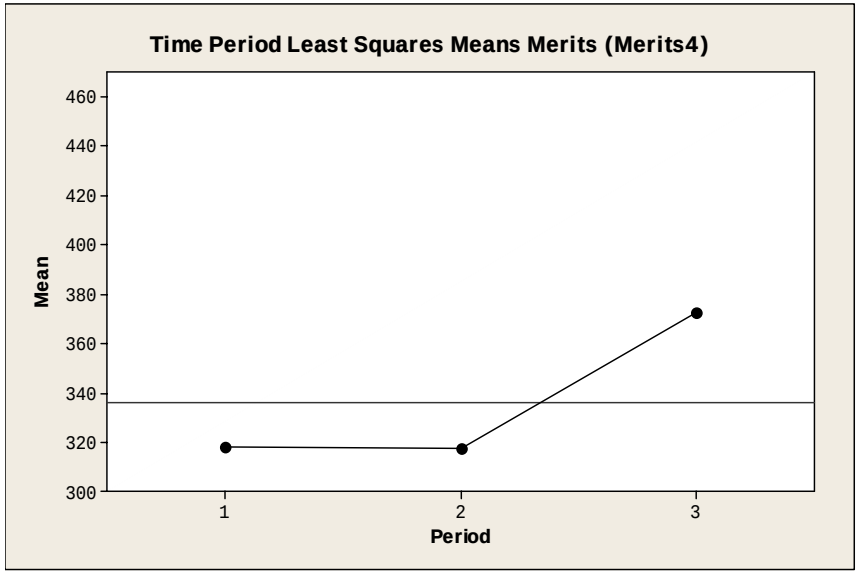
Statistical Models

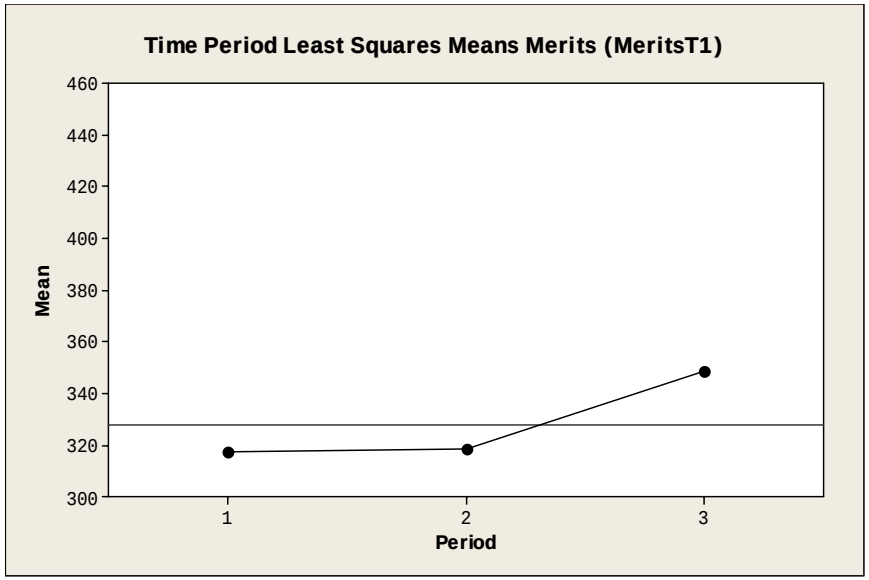
- IAS Merits = f (Lab, Time Period)
- Test HO that 3 Periods Divided Over Time Have Equal IAS Severity
  - Only Time Period 3 is Adjusted by Merit Proposals
    - Time Period 1 = First 7 Tests
    - Time Period 3 = Last 15 Tests
  - Statistical Evidence that Time Period 3 is Different is, Therefore, Not Good News for the Merit Proposal
- Not Enough Statistical Evidence that Time Period 3 has Higher Merits than Time Period 1 or 2 for MeritsT1 or MeritsT2 (or Merits4)
- LSM Results Graphed

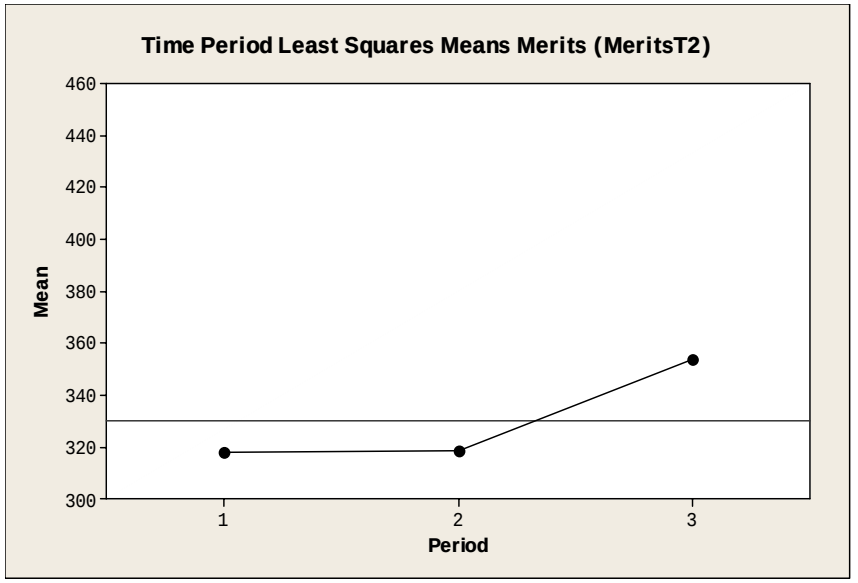
Graphs of Least Squares Means

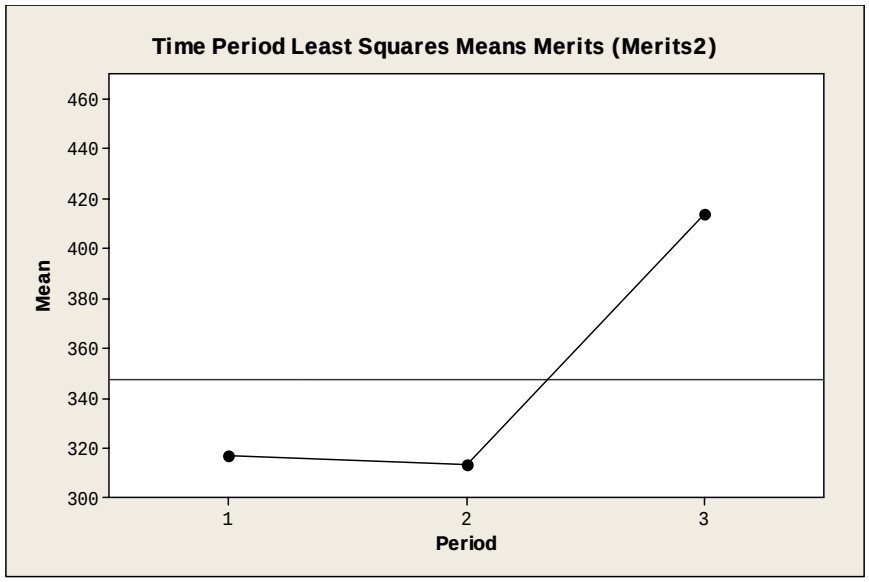
- The Least Squares Means for Each Time Period are Plotted for Each Merit System Proposal
- Note that there is Only ‘Not Enough’ Statistical Evidence of an Impact on ISM IAS Severity for Merits4, MeritsT1 and MeritsT2

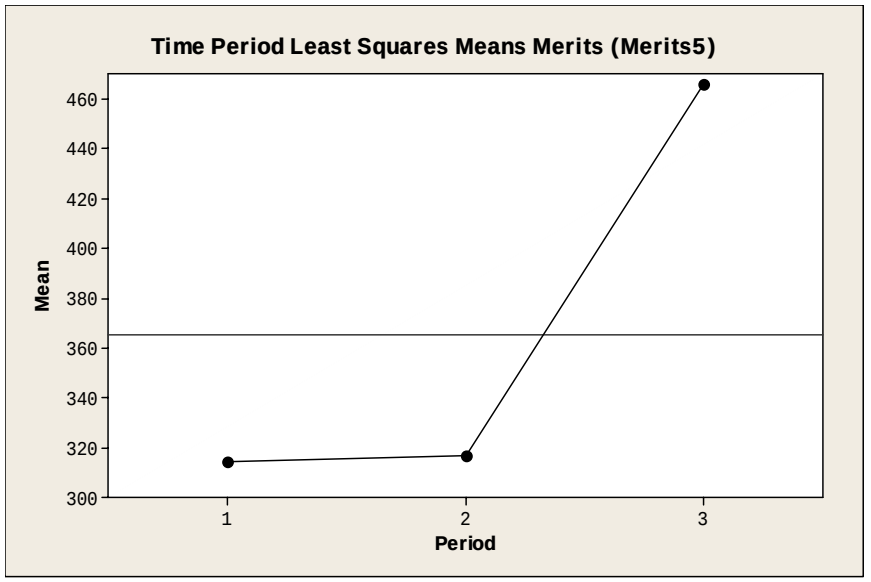

Time Period Least Squares Means Merits (Merits1)
Mean
460
440
420
400
380
360
340
320
300
1
2
3
Period

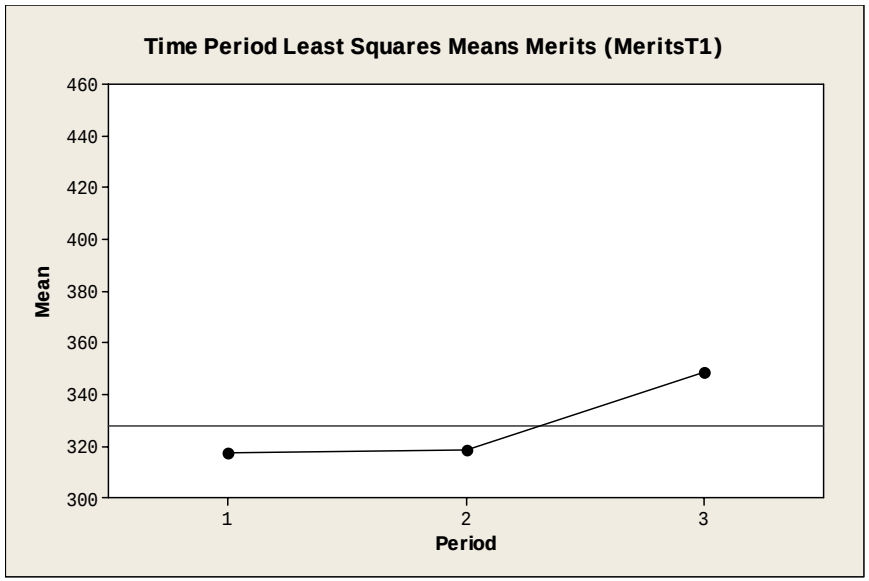

Time Period Least Squares Means Merits (Merits4)
Mean
460
440
420
400
380
360
340
320
300
1
2
3
Period

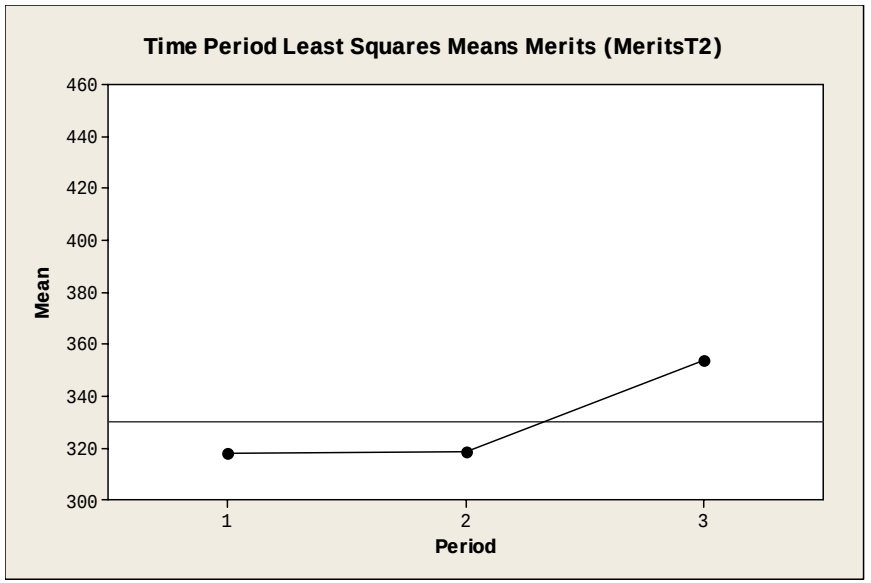

Time Period Least Squares Means Merits (MeritsT1)
Mean
460
440
420
400
380
360
340
320
300
1
2
3
Period


Time Period Least Squares Means Merits (MeritsT2)
Mean
460
440
420
400
380
360
340
320
300
1
2
3
Period


Time Period Least Squares Means Merits (Merits2)
Mean
460
440
420
400
380
360
340
320
300
1
2
3
Period


Time Period Least Squares Means Merits (Merits5)
Mean
460
440
420
400
380
360
340
320
300
1
2
3
Period


Time Period Least Squares Means Merits (MeritsT1)
Mean
460
440
420
400
380
360
340
320
300
1
2
3
Period


Time Period Least Squares Means Merits (MeritsT2)
Mean
460
440
420
400
380
360
340
320
300
1
2
3
Period

Attachment 4

Revised ISM IAS Merit Calculation Proposal

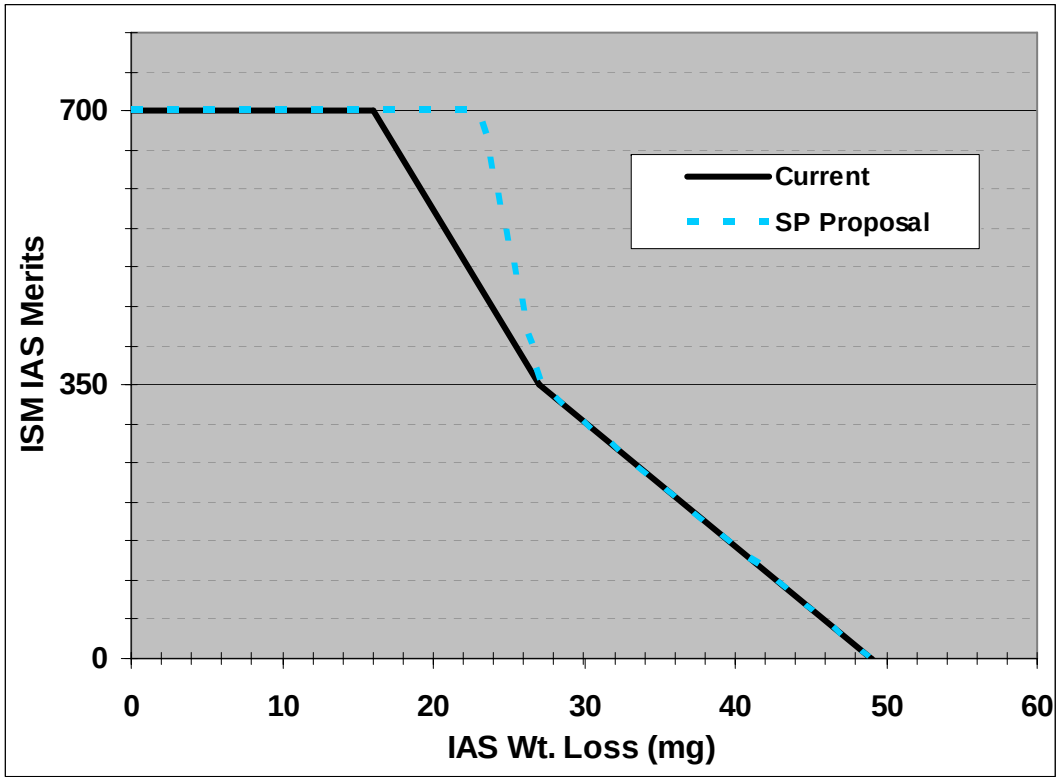
June 22, 2010

Pat Fetterman
Steve Kennedy
(discussed with Shawn Whitacre & Philpe Saad 6/21/10)

Summary

- Revised calculation for Cummins ISM IAS merits proposed by the SP on May 26 impacts only oils with IAS results below 27 mg since Anchor and Hard Limit points are unchanged:

		Current	SP Proposal
Full Merit	700	16	23
Anchor	350	27	27
Hard Limit	0	49	49



- Based on Cummins' original limit setting criteria, it is believed that adjusting the Anchor and potentially the Hard Limit points is justified
- Initial limit setting targeted 830-2 to generate significantly more than 350 merits
- Revised merit calculation being proposed to SP before moving onto HDEOCP

Background

Green highlighted areas:

1. **Average of the 10 tests on 830-2 when CJ-4 limits were established**
2. **Strategy to set the Anchor above the average of 830-2**

Attachment 8; Page 8 of 11

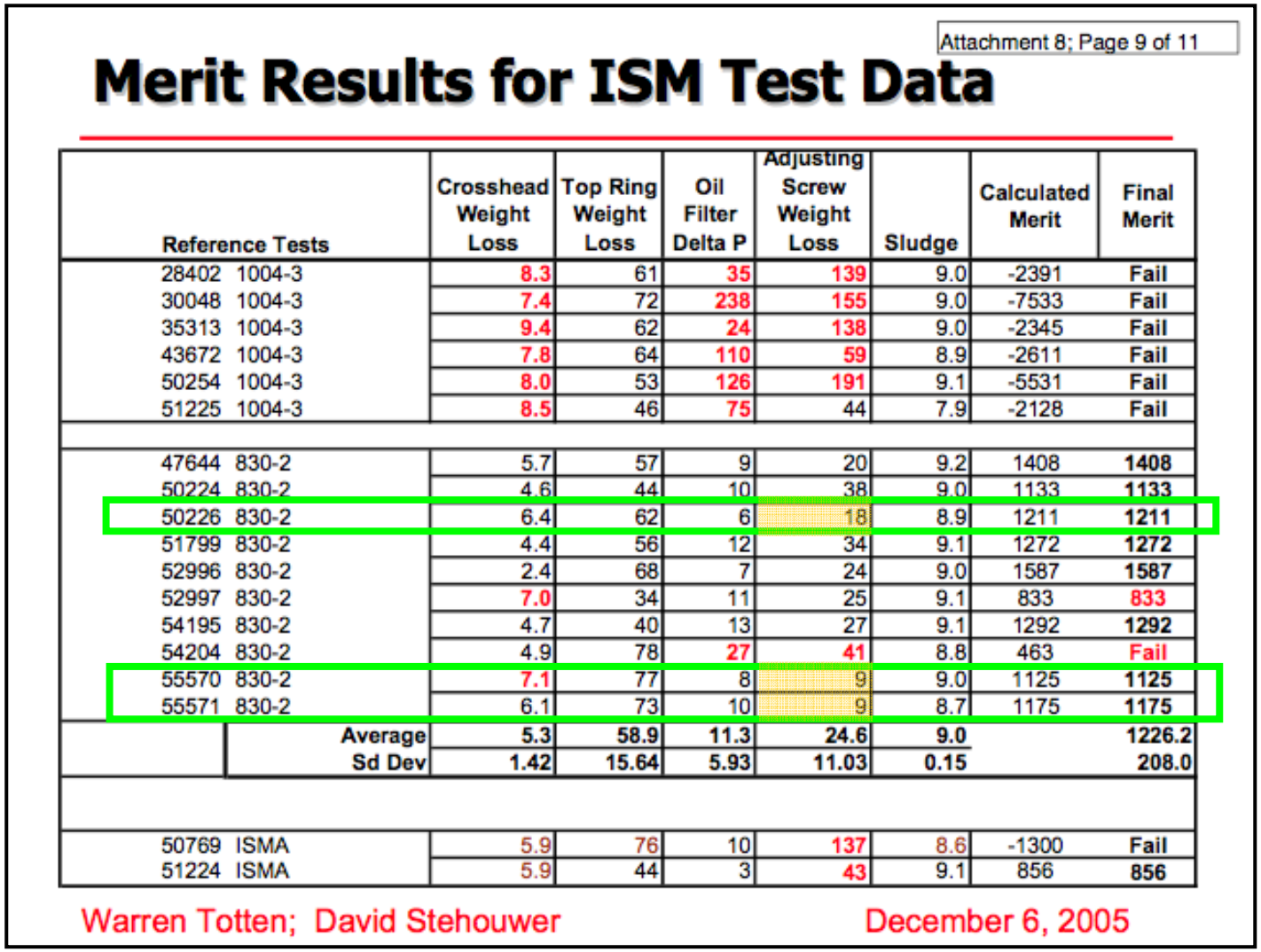
Revised ISM Merit System for PC-10

Criterion	Crosshead Weight Loss	Top Ring Weight Loss	Oil Filter Delta P	Adjusting Screw Weight Loss	Sludge	Total Merits
Weight	350	0	150	350	150	1000
Maximum	7.1	100	19	45	8.7	
Anchor	5.7		13	27	9.0	
Minimum	4.3		7	16	9.3	
Average	5.3	58.9	11.3	24.6	9.0	
St Dev	1.42	15.64	5.93	11.03	0.15	

- **Anchors set above mean of 830**
- **Maximum is 1 sigma above anchor (ASWL relaxed)**
- **TRWL is 100 max**
- **Weights are revised to emphasize wear parameters and minimize Sludge and OFDP**

Warren Totten; David Stehouwer December 6, 2005

Background



Attachment 8; Page 9 of 11

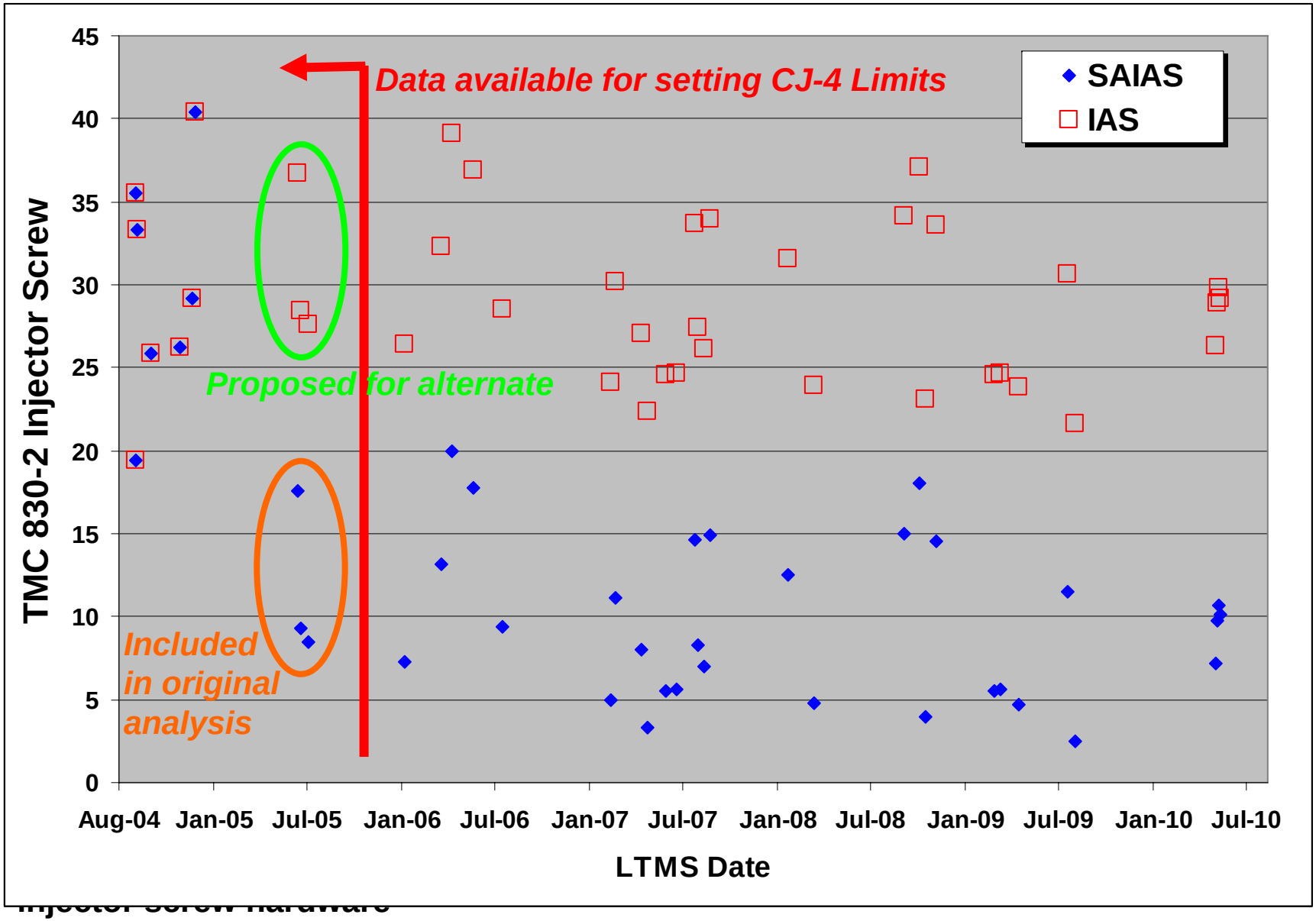
Merit Results for ISM Test Data

Reference Tests	Crosshead Weight Loss	Top Ring Weight Loss	Oil Filter Delta P	Adjusting Screw Weight Loss	Sludge	Calculated Merit	Final Merit
28402 1004-3	8.3	61	35	139	9.0	-2391	Fail
30048 1004-3	7.4	72	238	155	9.0	-7533	Fail
35313 1004-3	9.4	62	24	138	9.0	-2345	Fail
43672 1004-3	7.8	64	110	59	8.9	-2611	Fail
50254 1004-3	8.0	53	126	191	9.1	-5531	Fail
51225 1004-3	8.5	46	75	44	7.9	-2128	Fail
47644 830-2	5.7	57	9	20	9.2	1408	**1408**
50224 830-2	4.6	44	10	38	9.0	1133	**1133**
50226 830-2	6.4	62	6	18	8.9	1211	**1211**
51799 830-2	4.4	56	12	34	9.1	1272	**1272**
52996 830-2	2.4	68	7	24	9.0	1587	**1587**
52997 830-2	7.0	34	11	25	9.1	833	**833**
54195 830-2	4.7	40	13	27	9.1	1292	**1292**
54204 830-2	4.9	78	27	41	8.8	463	Fail
55570 830-2	7.1	77	8	9	9.0	1125	**1125**
55571 830-2	6.1	73	10	9	8.7	1175	**1175**
Average	**5.3**	**58.9**	**11.3**	**24.6**	**9.0**		**1226.2**
Sd Dev	**1.42**	**15.64**	**5.93**	**11.03**	**0.15**		**208.0**
50769 ISMA	5.9	76	10	137	8.6	-1300	Fail
51224 ISMA	5.9	44	3	43	9.1	856	**856**

Warren Totten; David Stehouwer December 6, 2005

- **Green highlighted areas show 3 tests that were corrected after the change to screened injector screw hardware**

Details



- Injector screw hardware

Data Summary / Proposal

TESTKEY	LAB	LTMSDATE	VAL	CHART	IND	ENKIT	SAIAS	SAIASCF	IAS
47644	D	20040901	AC	Y	830-2	ISM-012	19.4	0	19.4
50224	A	20040903	AC	Y	830-2	ISM-010	35.5	0	35.5
51799	G	20040905	AC	Y	830-2	ISM-013	33.3	0	33.3
52996	B	20041002	AC	Y	830-2	ISM-016	25.9	0	25.9
52997	D	20041126	AC	Y	830-2	ISM-025	26.2	0	26.2
54195	B	20041219	AC	Y	830-2	ISM-026	29.2	0	29.2
54204	G	20041226	AC	Y	830-2	ISM-031	40.4	0	40.4
50226	A	20050709	AC	Y	830-2	ISM-073	17.6	**19.1**	36.7
55570	A	20050716	AC	Y	830-2	ISM-069	9.3	**19.1**	28.4
55571	A	20050730	AC	Y	830-2	ISM-070	8.5	**19.1**	27.6
						First 7 Tests	30.0		
						Next 3 Tests	11.8		30.9
						First 10 Tests	24.5		30.3

Full Ref. Oil Database:	29.1

- **Based on updated analysis, revised recommendation:**
  - **Full Merit = 22 mg (similar to SP May recommendation)**
  - **Anchor = 31 mg (~2 mg above avg. of all 830-2 data)**
  - **Hard Fail = 43 mg (Anchor +2 stdev; similar to original approach)**

Proposal Rationale

- **CJ-4 ISM limits set when 10 830-2 (7 original + 3 post-corrected for IAS) data points were available; using the 3 corrected points more appropriate**

- **Anchor**
  - **IAS (and CWL) anchor points were set to be above the average of these 10 tests with no CF (HDEOCP minutes Dec-2005 & Jan-2006)**
    - **IAS Anchor = 27 mg relative to 24.5 mg average (+2.5 mg)**
  - **Average of the IAS for these 10 tests increases significantly when the CF is applied to the last 3 tests**
    - **24.5 mg increases to 30.3 mg**
  - **Updated IAS data supports increasing Anchor point to 30 – 33 mg based on original limit setting strategy**
  - **Approach is validated by full data set:**
    - **Original 10 tests (including CF) 30.3 mg**
    - **All chartable 830-2 data 29.1 mg**

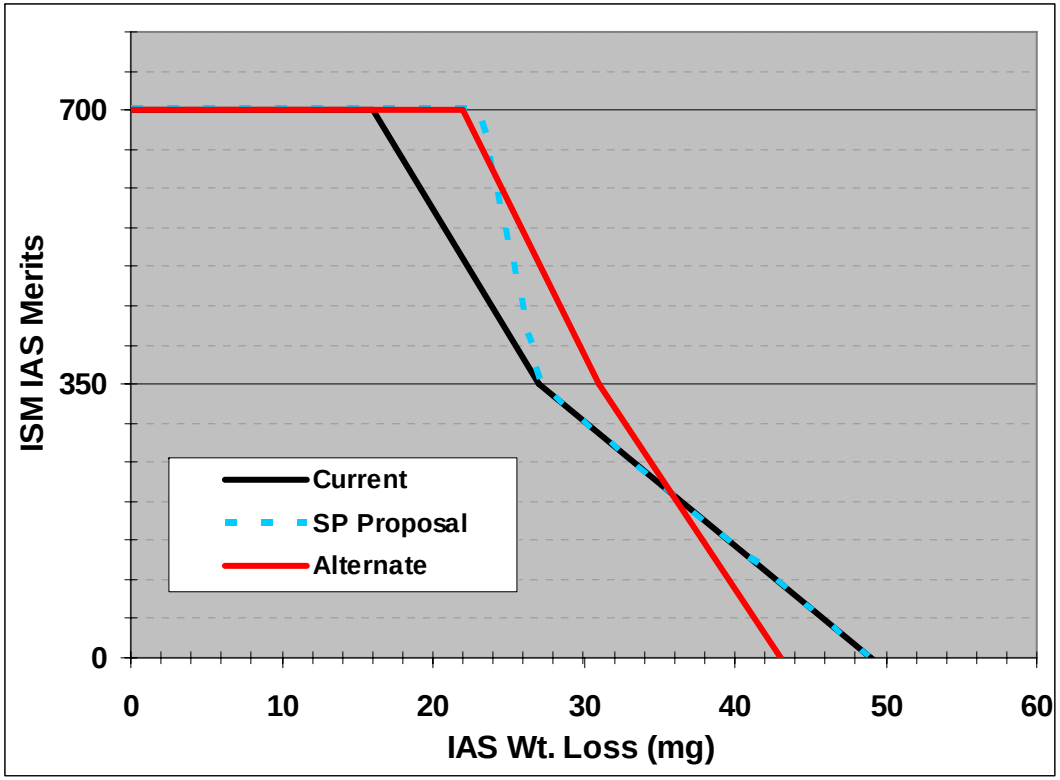
- **Full Merit**
  - **Adjust to an "achievable" level with 19.1 mg CF**

- **Hard Limit**
  - **Set closer to Anchor to reflect improved statistics, lower standard deviation**
    - **~6 mg versus 11 mg**

Proposal Summary

- Proposal increases avg. 830-2 IAS merits to match original intent with non-corrected data:
  - 10 data points (no CF) = 432
  - 40 data points (w/ CF) = 435
- Meets Cummins' original intent for 830-2 to generate >350 ISM merits
  - Current system fails to do this
  - SP proposal does this by drastically increasing the slope between the Anchor & Full Merit points
- **Request Cummins SP revisit IAS merits; evaluate this approach as potential recommendation to the HDEOCP**

		Current	SP Proposal	Alternate
Full Merit	700	16	23	22
Anchor	350	27	27	31
Hard Limit	0	49	49	43



ISM Injector Screw Merits				
SAIAS	IAS	SP (May)	Alternate	Comments
324	324	355	398	First 7 tests
683	288	288	372	Tests 8-10 only
432	313	335	390	First 10 Tests (when limts were set)
627	335	384	435	All chartible data (40 tests)

Cummins ISM IAS Merits (22-June 2010)

Back-Up

TESTKEY	LAB	LTMSDATE	VAL	CHART	IND	ENKIT	SAIAS	SAIASCF	IAS	Merit 1	Merit 2	SP	Alt
47644	D	20040901	AC	Y	830-2	ISM-012	19.4	0	19.4	**592**	*592*	**700**	**700**
50224	A	20040903	AC	Y	830-2	ISM-010	35.5	0	35.5	**215**	*215*	**215**	**219**
51799	G	20040905	AC	Y	830-2	ISM-013	33.3	0	33.3	**250**	*250*	**250**	**283**
52996	B	20041002	AC	Y	830-2	ISM-016	25.9	0	25.9	**385**	*385*	**446**	**548**
52997	D	20041126	AC	Y	830-2	ISM-025	26.2	0	26.2	375	*375*	420	537
54195	B	20041219	AC	Y	830-2	ISM-026	29.2	0	29.2	315	*315*	315	420
54204	G	20041226	AC	Y	830-2	ISM-031	40.4	0	40.4	137	*137*	137	76
50226	A	20050709	AC	Y	830-2	ISM-073	17.6	**19.1**	36.7	649	*196*	196	184
55570	A	20050716	AC	Y	830-2	ISM-069	9.3	**19.1**	28.4	700	*328*	328	451
55571	A	20050730	AC	Y	830-2	ISM-070	8.5	**19.1**	27.6	700	*340*	340	482
						First 7 Tests	30.0			324	324	355	398
						Next 3 Tests	11.8		30.9	683	288	288	372
						First 10 Tests	24.5		30.3	432	313	335	390

Full Ref. Oil Database: 29.1 435

Attachment 5

LUBRICANT TEST MONITORING SYSTEM
Second Edition

Contents

F. SECOND EDITION CONTROL CHARTS

i. Reference Qualification

For the sake of brevity and simplicity, we will assume in this section that the severity adjustment entity is a laboratory. If, as described above, a compelling case for other severity adjustment entity (e.g., engine) has been accepted, details of this section are slightly modified (see Appendix F).

With the default system, the first stand within a laboratory requires three reference tests for initial non-reference testing qualification. These reference tests are run consecutively, before non-references, and may include precision study oils as well as reference oils. Calibration status is not judged until the final reference test in the consecutive string is complete.

In order to remain qualified for non-reference oil testing, a test stand shall begin a reference oil test after no more than 18 valid non-reference oil tests in the stand or no later than 15 months following the completion of the stand's previous qualifying reference oil test, whichever comes first. If more than 15 valid non-reference oil tests or more than 12 months are allowed in the standard reference period, then the laboratory is required to run 1 acceptable reference per six month interval. The time limits could be decreased if appropriate by the Surveillance Panel. These intervals might be reduced or increased as a function of monitoring. If reference period extensions push intervals over the 15 tests or 12 months limits, the requirement to run 1 acceptable reference per six month interval is **not** invoked.

If two full length reference oil tests are declared operationally invalid during the attempt to calibrate an existing stand, increases to the reference interval that would otherwise apply, will not occur in this situation.

ii. Severity adjustment entity Charting and Actions

For each severity adjustment entity, let

X_i = i^{th} test result in original units in end of test order,
T_i = i^{th} test result in appropriate units in end of test order,
(T_i=X_i unless a transformation is used in which case T_i=transformed (X_i))
Y_i = i^{th} standardized test result = (T_i – target) / (standard deviation),
(Target and standard deviation are as currently defined for the reference oil used in the reference test)
Z_i = EWMA = $\lambda Y_i + (1- \lambda) Z_{i-1}$,
(By default, λ=0.2. With sufficient data and appropriate analyses, λ could be optimized by Box procedure minimizing sum of squares for prediction, $\sum_i e_i^2$, see Reference 1, pages 87-88.)
(Fast start is used, i.e., Z_0=average of Y_1, Y_2, and Y_3.)
and,

e_i = prediction error from EWMA = $Y_i - Z_{i-1}$.

For each severity adjustment entity, chart Y_i, Z_i, and e_i versus i. Z_i is used as an adjustment chart to promote similar severity across severity adjustment entities. Shewhart charts of the e_i's indicate whether we know the relative performance of the severity adjustment entity well enough to adequately severity adjust using the Z_i.

Level 1, 2, and 3 limits and their implications for prediction error monitoring are described in Appendix F. Suggested limits for prediction error monitoring are shown in the following table. Derivation of these limits is explained in Appendix G. As discussed, in Section G, it is each surveillance panel's responsibility to select an appropriate set of limits for each of the prediction error monitoring parameters.

Shewhart Limits for Prediction Error Monitoring Parameters

Shewhart Chart of Prediction Error $e_i = Y_i - Z_{i-1}$			
Limit Type	Tightened	Default	Loosened
Level 1	1.054	1.351	1.734
Level 2	1.351	1.734	2.066
Level 3	1.734	2.066	2.452

Level 1 and 2 limits and their implications for severity monitoring and adjustment are described in Appendix F. The default recommendation for the level 1 limit for each severity adjustment parameter is zero. That is, continuous or no threshold severity adjustment is recommended. Selection of EWMA level 2 limits should be made by the surveillance panel in original engineering units as discussed in Section G.

iii. Industry Charting and Actions

For the entire testing industry, let

X_i = i^{th} test result in original units in end of test order,
T_i = i^{th} test result in appropriate units in end of test order,
(T_i=X_i unless a transformation is used in which case T_i=transformed (X_i))
Y_i = i^{th} standardized test result = Y_i = (T_i – target) / (standard deviation),
(Target and standard deviation are as currently defined for the reference oil used in the reference test)
and,
Z_i = EWMA = $\lambda Y_i + (1- \lambda) Z_{i-1}$.
(By default, λ=0.2. With sufficient data and appropriate analyses, λ could be optimized by Box procedure minimizing sum of squares for prediction, $\sum_i e_i^2$, see Reference 1, pages 87-88.)

(Fast start is used, i.e., Z_0=average of Y_1, Y_2, and Y_3.)

Industry Z_i charts without application of severity adjustment can indicate when a change in testing has caused the entire industry to drift. Such drift would be captured by severity adjustments. However, the industry chart might alert faster than individual testing entities. It might also indicate when the entire industry has shifted to the extent that the originally intended engine oil performance characteristics can no longer be reliably measured.

TMC will maintain industry Z_i charts and include them in semiannual reports. To enhance understanding of trends, individual reference entities will be indicated on the charts through color or symbols in coded form. Further, when the following limits are exceeded in absolute value, the TMC will take actions as indicated in Appendix F.

As described in Section G, the surveillance panel should determine level 2 limits based on mechanistic understanding of the test and discussed in engineering units. Suggested level 1 limits are shown in the following table.

Industry EWMA Limits for Severity Adjustment Parameters

EWMA of Standardized Test Result $Z_i = \lambda(Y_i) + (1 - \lambda)Z_{i-1}$			
Limit Type	Tightened	Default	Loosened
Level 1	0.548	0.653	0.775

G. SURVEILLANCE PANEL GUIDELINES FOR IMPLEMENTING LTMS VERSION 2

Surveillance panels have the ultimate responsibility and authority for test development, target creation, and implementation of LTMS. However, given the importance of LTMS to test definition, it is advisable to include industry statisticians early and throughout the test development process. LTMS implementation for a test typically includes an engagement of industry statisticians with the surveillance panel or test development task force. From analyses of precision study data and/or historical data, the statisticians will present a recommendation to the surveillance panel for most of the LTMS parameters. It is the responsibility of the surveillance panel to review and endorse or modify the proposed system parameters. Other system parameters should originate at the surveillance panel. Selection of these other parameters by the surveillance panel might be informed by data analyses; but, the criteria for selection should primarily be determined by subject matter experts.

i. Existing Tests

Using historical data from an existing test, potential parameters can be explored. The goal is not to determine exactly where each severity adjustment entity would start but to explore in a limited way whether various parameter settings might have more accurately compensated for past situations.

Each severity adjustment entity would begin its application of Version 2 LTMS with its first reference run in the new regime. It would be the decision of the surveillance panel whether all entities would start simultaneously with a reference test or with each entity's next reference test. For example, if new hardware were being introduced, the surveillance panel might specify that each entity run a reference with new hardware before starting another non-reference test.

ii. Lab and industry level 2 Z_i limits

Level 2 limits for severity adjustment entity Z_i charts are intended to identify when a severity adjustment entity is so far from target that it cannot discriminate oil performance in the same manner as when testing is on target. This choice of limits is based on subject matter expertise related to the mechanism being evaluated. For example, when using a 0 to 10 cleanliness rating scale, if the target is 5 and a severity adjustment entity is obtaining results close to 10, then the entity will not likely be able to discriminate oil performance because all oils would be producing very clean results due to the severity of the entity. These limits must be determined for each parameter in original units. Limits need not be symmetric, i.e., severe and mild limits might not be the same distance from the target in any metric. Surveillance panels should consider that two labs could be farther apart than the difference between mild and severe limits; but, the non-reference tests would not be severity adjusted farther than those limits. The panel should consider Z_i lag in setting limits.

One form of help in making these determinations could come from plotting original unit results (x_i) versus deviation from target in standardized units (y_i) for reference oil(s) and theoretical pass limit oil. It would also be very helpful for additive companies to bring input from formulators to the surveillance panel.

Level 2 limits for industry Z_i charts are intended to mandate alert to the industry that something in the test appears to be causing a severity shift. At that point the industry must evaluate whether normal severity adjustments are adequate and also investigate whether the cause of the shift can be determined. Level 1 limits for industry Z_i charts can trigger a TMC investigation with possible involvement by the surveillance panel. Level 2 triggers, however, require the immediate involvement by the surveillance panel.

iii. Prediction error monitoring parameters, severity adjustment parameters, and reference period adjustment parameters

When multiple pass / fail criteria are defined for a test, statisticians' preparation for engagement would include evaluation of correlation among the criteria. It is generally detrimental to include redundant measures of oil performance. For purposes of LTMS, redundant measures bias ability of the system to detect appropriate signals. While all passing criteria should have severity adjustments in the system, it might reduce the effect of redundant criteria if test parameters of lesser importance or meaning are not included as prediction error monitoring parameters. These parameters would not be subject to the prediction error (e_i) judgments of reference test acceptability. As part of the statisticians' engagement, the surveillance panel should consider whether a subset of criteria should be designated as severity adjustment only parameters. Generally, this parameter bifurcation could be accomplished by declaring whether each parameter is e_i only, Z_i only, or both. However, if special circumstances justify it, designation of parameters for reference period adjustment might be different from designation of parameters for prediction error monitoring.

One of the severity adjustment parameters is the industry approved severity adjustment standard deviation. As part of the implementation engagement, statisticians will propose standard deviations appropriate at the pass limit for the criterion. The statistician will suggest transformations, if appropriate. It is hoped that transformations homogenize variability. If adequate transformations are not determined, statisticians and the surveillance panel need to consider how to deal with multiple pass limits such as when a test is used in multiple categories and whether the severity adjustment standard deviation remains appropriate when the test experiences large severity shifts.

After designating whether each pass / fail criterion is a prediction error monitoring parameter, severity adjustment parameter, and / or a reference period adjustment parameter, appropriate limits should be addressed. Unless there is justification for a difference, default limits should be used as shown in Section F. If a specific pass / fail criterion requires more severe or more lenient limits, suggestions for these limits are included in Section F.

The surveillance panel should decide whether time extensions should be included with test count extensions and, if they are to be included, whether the extensions should be sufficient time to allow extended test count or if the extensions should be percentage time extensions similar to test count extensions.

For tests with merit systems used in passing criteria, the potential impact of LTMS should also be considered. Unless there is clear evidence for the specific test that another approach is better, all of the parameters should be monitored and adjusted individually. Reference test disposition decisions should be made based on individual parameter monitoring. Total merits should also be monitored.
The surveillance panel should consider whether the system would allow reference acceptance based on test results that are not meaningful. The surveillance panel should determine whether e_i limits stacked on top of Z_i limits could mean a result outside a reasonable range could be acceptable.

iv. Annual review

The Technical Guidance Committee (TGC) will organize and conduct annual reviews of the LTMS system in its entirety. Surveillance Panel chairmen are ex officio members of the TGC. The chairmen should prepare with their surveillance panel for these reviews. As part of this preparation, the surveillance panel together with the TMC will review data to determine if any laboratory or laboratories exhibit(s) unusual performance. Such unusual performance might include but not be limited to severity differences from other laboratories, poor relative precision, high invalid rates, and etcetera. Concerns identified in LTMS data and in the LTMS process should be brought forward to the TGC annual review meetings.

v. LTMS documentation

It is very desirable that we have consistent documentation of LTMS for individual test types. Someone needing this information should be able to find it in an analogous place regardless of test type.

Some aspects of LTMS are more permanent and more logically contained in the test method. As part of the test method, they are subject to revision by information letter. This includes definitions of new laboratories and new stands, specification of basic reference intervals, reference oil targets, and implications of exceeding LTMS limits.

Other parts of LTMS definition are more transient. They might be subject to periodic update or tunable during the annual review. Changes are suggested by data and analyses. They are subject to the consensus and timing guidelines as specified in section K, below. These latter aspects should be documented in a compendium of test type specific LTMS parameters maintained by the Test Monitoring Center. They include reference oil standard deviations, limits for e_i and Z_i monitoring, and lambdas for Z_i calculations.

APPENDIX F
TEMPLATES FOR VERSION 2 LABORATORY AND STAND BASED LTMS

1. *<Test Name>* LTMS Requirements(A Laboratory Based Severity Adjustment System)

TEST METHOD PORTION

The following are the specific *<Test Name>* calibration test requirements.

A. Reference Oils and Parameters

The prediction error monitoring parameter is Parameter 1 and the severity adjustment only parameter is Parameter 2. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM *<Test Name>* Surveillance Panel. The targets for the current reference oils for each parameter are presented below.

PARAMETER 1
Unit of Measure: *units(including transform if any)*
PREDICTION ERROR MONITORING PARAMETER

Reference Oil	Target

PARAMETER 2
Unit of Measure: *units(including transform if any)*
SEVERITY ADJUSTMENT ONLY PARAMETER

Reference Oil	Target

B. Acceptance Criteria

1. New test labs [It is preferred that the definition of a new laboratory appears in the test method. But if it doesn't or requires clarification, it should be done here.]

a. A minimum of three (3) operationally valid reference and/or matrix tests must be run on the first test stand in a new laboratory.

- Note that industry matrix runs may be included, as well as reference runs, at the discretion of the surveillance panel.

b. Following the necessary tests, check the status of the control charts and follow the prescribed actions.

c. If two full length reference oil tests are declared operationally invalid during the attempt to calibrate a stand, then an increase in the reference interval per section 5.d may not be granted.

2. Existing Test Lab

a. New test stands in an existing lab, and test stands in an existing test lab that have not run an acceptable reference in the past two years, may calibrate with one test provided Level 1 limit requirement is met. Otherwise a second test is required for calibration.

b. For an existing test stand in an existing lab run one test

c. Following an operationally valid reference oil calibration test, check the status of the control charts and follow the prescribed actions.

d. If two full length reference oil tests are declared operationally invalid during the attempt to calibrate a stand, then an increase in the reference interval per section 5.d may not be granted.

3. Reference Oil Assignment

Once a test stand has been accepted into the system, the TMC will assign reference oils for continuing calibration according to the following reference oil mix:

- 100% of the scheduled calibration tests should be conducted on reference oils <*Oil XXX*>, <*Oil YYY*>, and <*Oil ZZZ*> or subsequent approved reblends.

5. Chart Status

The following are the steps that must be taken in the case of exceeding chart limits. The steps are listed in order of priority, although charts should be studied simultaneously to determine the cause(s) of a problem. In the case of multiple alarms, contact the TMC for guidance. The laboratory always has the option of removing any stand from the system.

a. Shewhart Chart of Prediction Error (e_i) for **prediction error monitoring parameters only**

- Level 3
  - Immediately conduct one additional reference test in the stand that triggered the alarm. Do not update the control charts for the lab until the follow up reference test is completed and the ExI analysis, per Section 5.c (below), has been performed.
- Level 2
  - Reduce the number of tests allowed in the calibration period in the stand that triggered the alarm to [enter number of tests representing 80% of the standard calibration period].
- Level 1

- The level 1 limit applies in situations that have been pre-determined by the surveillance panel to have a potential impact on test results. These situations may include the introduction of new critical parts, fuel batches, reference oil reblends, or other test components. When these conditions have been met and a level 1 alarm is triggered, immediately conduct one additional reference test in the stand that triggered the alarm.

- The level 1 limit also applies to a stand in an existing test lab that has not run an acceptable reference in the past two years. The stand can calibrate with one test if the level 1 limits are not exceeded. Otherwise, immediately conduct another reference test in the stand.

b. Reference entity EWMA of Standardized Test Result (Z_i) for **all parameters**

- Level 2

  - Immediately conduct one additional reference test either

    - in the stand that triggered the alarm, or
    - in the stand that is next due for calibration.
      - The stand that triggered the alarm is not calibrated for non-reference testing without further reference testing.

- Level 1

  - The level 1 limit applies to all reference tests that are control charted, even when other alarms have been triggered. Level 1 uses Z_i to determine the laboratory severity adjustment (SA). Calculate the laboratory SA for each parameter as follows and confirm the calculation with the TMC:

    $SA = -Z_i \times s_{SA}$

    where s_{SA} = industry approved severity adjustment standard deviation

c. Excessive influence (ExI) Analysis for **prediction error monitoring parameters only**

- The ExI analysis is performed anytime that a lab e_i level 3 alarm is triggered. As prescribed in Section 5.a, Level 3, a follow up reference test is run. The following comparisons then determine whether the value of Y_i is modified to limit its influence on LTMS. Y_{i+1} is the next completed reference in the laboratory after the level 3 alarm

  i) If $|Y_i - Y_{i+1}| \leq e_i$ level 3 limit, then Y_i is equal to the value originally determined.

  ii) If $Y_i > Z_{i-1}$ and $Y_i - Y_{i+1} > e_i$ level 3 limit, then let
  $Y_i = e_i$ level 3 limit + Z_{i-1}.

  iii) If $Y_i \leq Z_{i-1}$ and $Y_i - Y_{i+1} < -e_i$ level 3 limit, then let
  $Y_i = -e_i$ level 3 limit + Z_{i-1}.

iv) If none of i), ii), or iii) is true, then Y_i is equal to the value originally determined.

Where: i = test that originally triggered level 3 alarm,
i-1 = test prior to alarm trigger, and
i+1 = test immediately following alarm trigger.

Once the proper Y_i value has been determined, update the charts. Confirm calculations with the TMC. The laboratory and the TMC maintain a record of the modification.

d. Increase in the Number of Tests for the Stand Calibration Period

- The number of tests allowed in a stand calibration period, for existing stands only, may be increased if the previous test was an acceptable reference based upon the chart results for all prediction error monitoring parameters as follows:

  – If $|e_i| \leq E_e$, then the number of tests allowed for that calibration period may be increased by [insert number of tests representing 20% of the standard calibration period], [if surveillance panel opts to include ", and the time between references may be increased by" insert time extension required to extend number of tests or time period representing 20% of the standard period], or

  – If $|e_i| \leq E_e$ and $|Z_i| \leq Z_e$, then the number of tests allowed for that calibration period may be increased by [insert number of tests representing 40% of the standard calibration period] [if surveillance panel opts to include ",and the time between references may be increased by" insert time extension required to extend number of tests or time period representing 40% of the standard period ".

  Confirm calculations with the TMC.

- If two full length reference oil tests are declared operationally invalid during the calibration sequence in the same stand, then the increase in calibration period will not be granted

e. Industry EWMA of Standardized Test Result (Z_i) for **all parameters**

- Level 2

  – TMC informs the surveillance panel that the limit has been exceeded. The surveillance panel then investigates and pursues resolution of the alarm.

- Level 1

- The TMC investigates whether severity adjustments are adequately addressing the trend, investigates the possible causes, and communicates as appropriate with industry.

TMC COMPENDIUM PORTION

The following are the specific *<Test Name>* calibration test requirements.

A. Reference Oils and Parameters

The prediction error monitoring parameter is Parameter 1 and the severity adjustment only parameter is Parameter 2. The reference oils required for test stand and test laboratory calibration are reference oils accepted by the ASTM *<Test Name>* Surveillance Panel. The standard deviations for the current reference oils for each parameter are presented below.

PARAMETER 1
Unit of Measure: *units(including transform if any)*
PREDICTION ERROR MONITORING PARAMETER

Reference Oil	Standard Deviation

PARAMETER 2
Unit of Measure: *units(including transform if any)*
SEVERITY ADJUSTMENT ONLY PARAMETER

Reference Oil	Standard Deviation

B. Acceptance Criteria

4. Adjustment (Z_i) and Monitoring (e_i) Charts

In Section 1, the construction of the adjustment and monitoring charts used in the Lubricant Test Monitoring System are outlined. The constants used for the construction of the control charts for the <*Test Name*>, and the adjustment and monitoring chart limits, are shown below.

Laboratory Shewhart Limits for Prediction Error Monitoring Parameters

Shewhart Chart of Prediction Error $e_i = Y_i - Z_{i-1}$	
Limit Type	Limit*
Level 3	TBD
Level 2	TBD
Level 1	TBD

Laboratory EWMA Limits for Each Severity Adjustment Parameter

EWMA of Standardized Test Result $Z_i = \lambda(Y_i) + (1 - \lambda)Z_{i-1}$		
Limit Type	λ	Limit
Level 2 Upper Limit	0.2	TBD by SP Input
Level 2 Lower Limit	0.2	TBD by SP Input
Level 1	0.2	0

Laboratory Prediction Error and EWMA Reference Period Extension Limits for Each Reference Period Adjustment Parameter

Limit Type	Limit
E_e	1.05
E_Z	0.66

Industry EWMA Limits for Each Severity Adjustment Parameter

EWMA of Standardized Test Result $Z_i = \lambda(Y_i) + (1 - \lambda)Z_{i-1}$		
Limit Type	λ	Limit
Level 2 Upper Limit	0.2	TBD by SP Input
Level 2 Lower Limit	0.2	TBD by SP Input
Level 1	0.2	TBD

APPENDIX G
DEVELOPMENT OF VARIANCE ESTIMATORS AND CHART LIMITS

If we assume (as we assumed for creation of the original LTMS in accord with traditional Statistical Process Control) the Y_i to be independent and identically distributed, the variance for the EWMA can be estimated by

$$\hat{\sigma}^2_{Z_i} = \hat{\sigma}^2_{Y_i}\left[1-(1-\lambda)^{2i}\right]\left[\lambda/(2-\lambda)\right] \text{ for i=0,1,2,3, …}$$

As i increases, the first bracketed factor decreases and we might approximate the variance of the EWMA as

$$\hat{\sigma}^2_{Z_i} = \hat{\sigma}^2_{Y_i}\left[\lambda/(2-\lambda)\right]$$

Then, if we assume normalization makes Y_i ~N(0,1), we might further simplify to

$$\hat{\sigma}^2_{Z_i} = \left[\lambda/(2-\lambda)\right]$$

And limits for the EWMA chart for monitoring severity (Z_i plotted against completion date order) might be expressed as

$$0 \pm c\sqrt{\frac{\lambda}{2-\lambda}}$$

Similarly, the variance of e_i might then be approximately estimated by

$$\hat{\sigma}^2_{e_i} = 1+\left[\lambda/(2-\lambda)\right]$$

And limits for Shewhart charts of the e_i's might be expressed as

$$0 \pm c\sqrt{\left[1+\left(\lambda/(2-\lambda)\right)\right]}$$

In traditional SPC, the constants, c, are typically selected with false alarm error rates and average run lengths in mind. Under the assumptions for traditional SPC, these false alarm error rates and run lengths have been well studied and documented through application of probability theory or simulation. In fact, we believe the Y_i to be non-stationary (i.e., there is not a constant mean) and to frequently exhibit autocorrelation. Limits in version 2 of LTMS (which is a system for monitoring and adjustment rather than traditional SPC) do not have the same meaning and the probability theory and simulations are not applicable.

IF the EWMA or, equivalently ARIMA(0,1,1), adequately models the data such that the residuals from the model are approximately independent and identically distributed as N(0, σ^2_r) and σ^2_r could be estimated as the mean squared error from the EWMA prediction, then we would use $\hat{\sigma}^2_r$ to estimate $\sigma^2_{\hat{\delta}_t}$. However, we suggest the following

approach to start LTMS for a test unless adequate data and analyses have been done to implement the more rigorous approach. Residuals from the EWMA and alternate models should be reviewed along with regular review of reference oil variances.

The default approach is then to use the above along with the following table of constants to determine limits for a test. The resulting limits are shown in Section F. Surveillance panels should judge whether each pass criterion should be judged as for e_i, Z_i, or both and, if judged for that chart, whether the default, tightened, or loosened limits should be used.

Laboratory Shewhart Constants for Prediction Error Monitoring Parameters

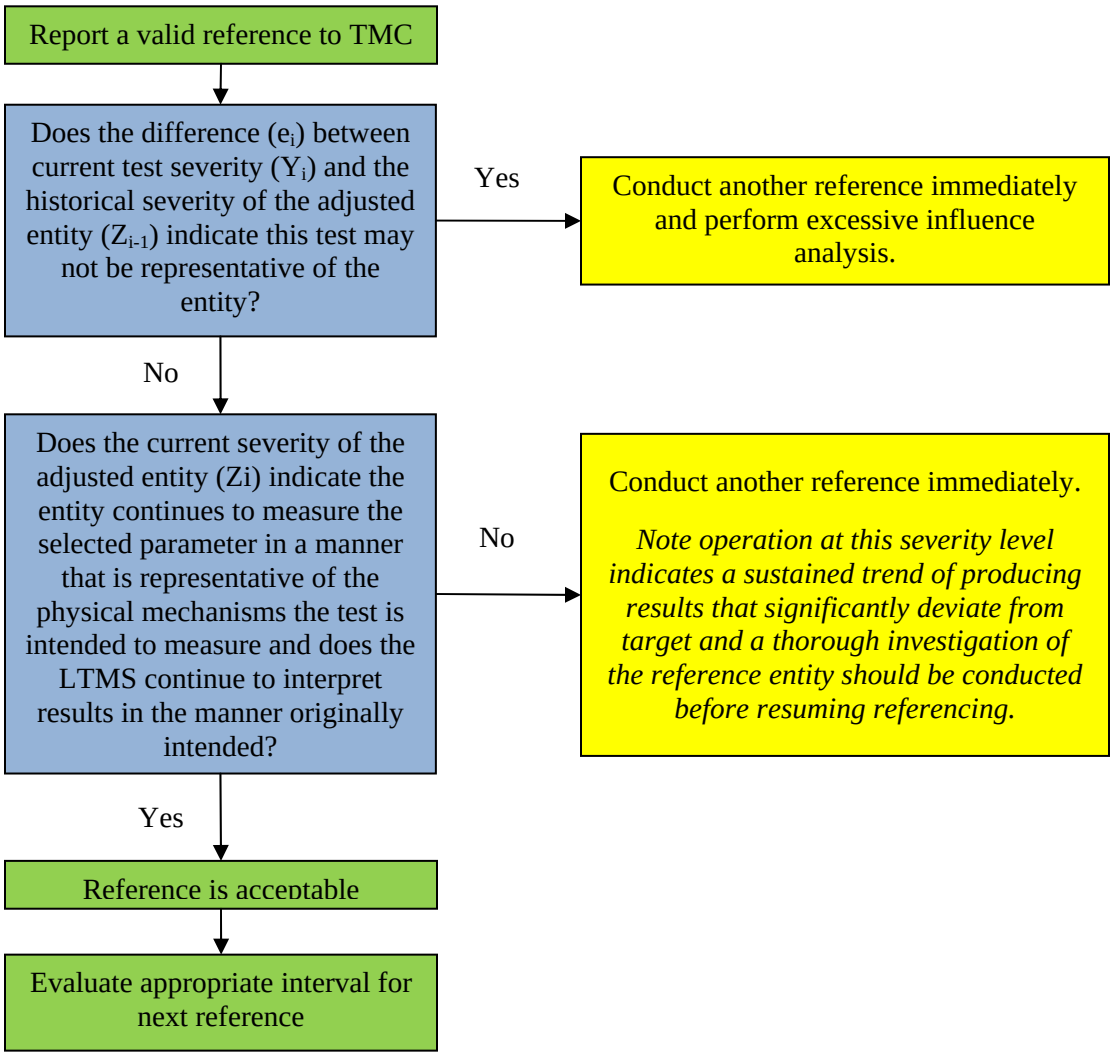
Shewhart Chart of Prediction Error ei = Yi – Zi-1			
Limit Type	Tightened c	Default c	Loosened c
Level 1	1.000	1.282	1.645
Level 2	1.282	1.645	1.960
Level 3	1.645	1.960	2.326

Industry EWMA Constants for Severity Adjustment Parameters

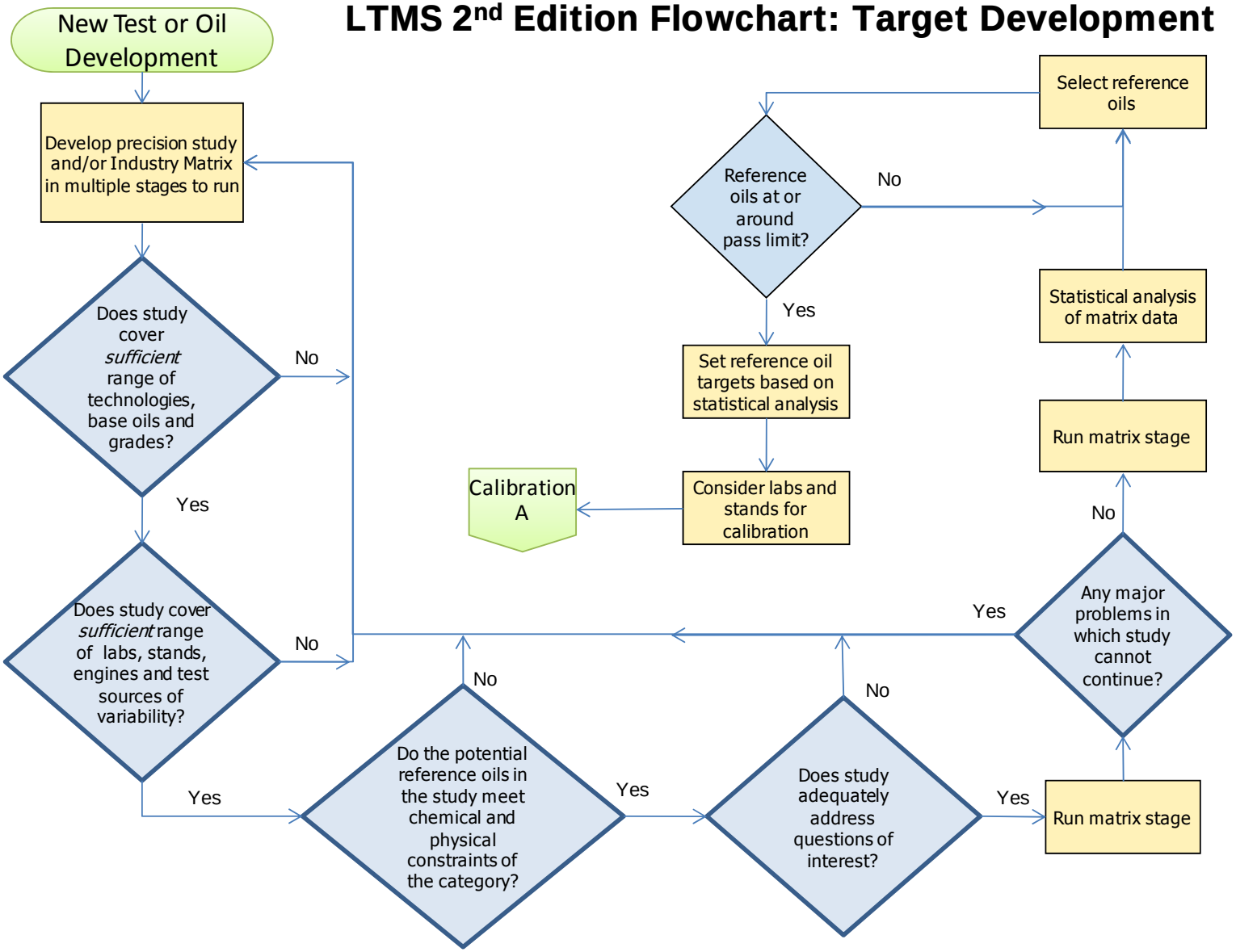
EWMA of Standardized Test Result Zi = λ(Yi) + (1 – λ)Zi-1				EWMA of Standardized Test Result Zi = λ(Yi) + (1 – λ)Zi-1			
Limit Type	Tightened c	Default c	Loosened c	Limit Type	Tightened c	Default c	Loosened c
Level 1	1.645	1.960	2.326	Level 1	1.65	1.96	2.33

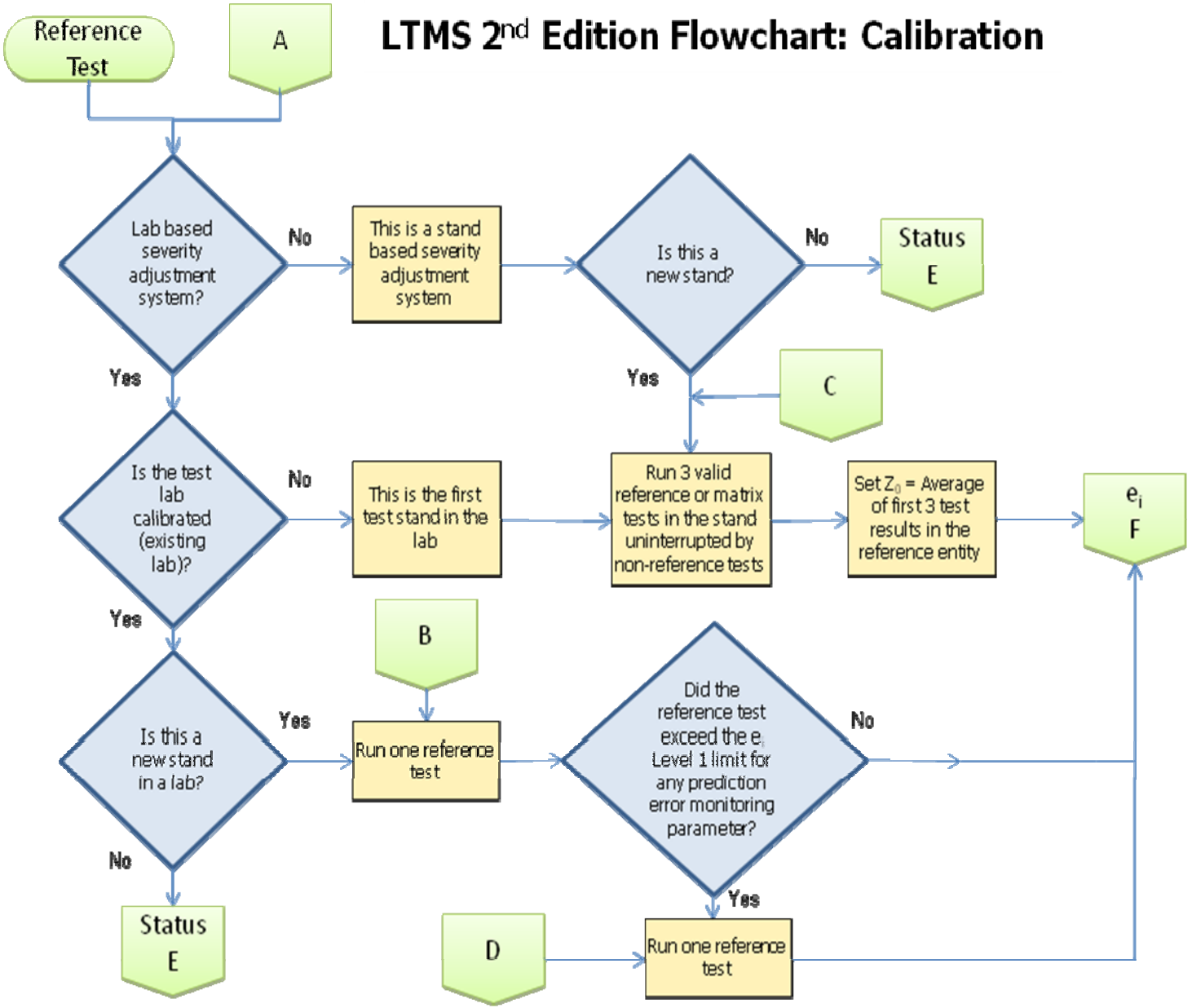
APPENDIX H
FLOW CHARTS

High-Level LTMS 2nd Edition Flowchart

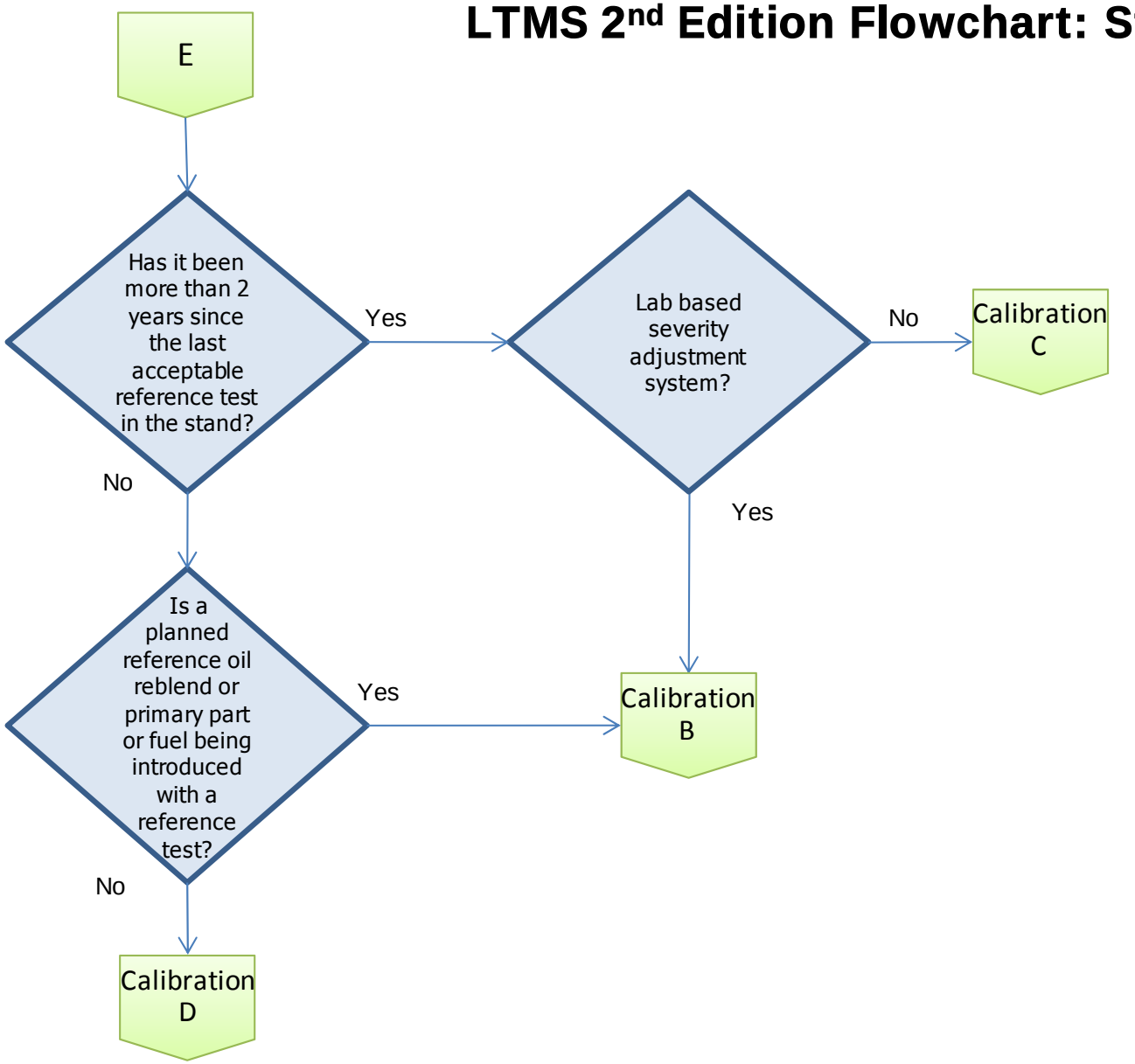


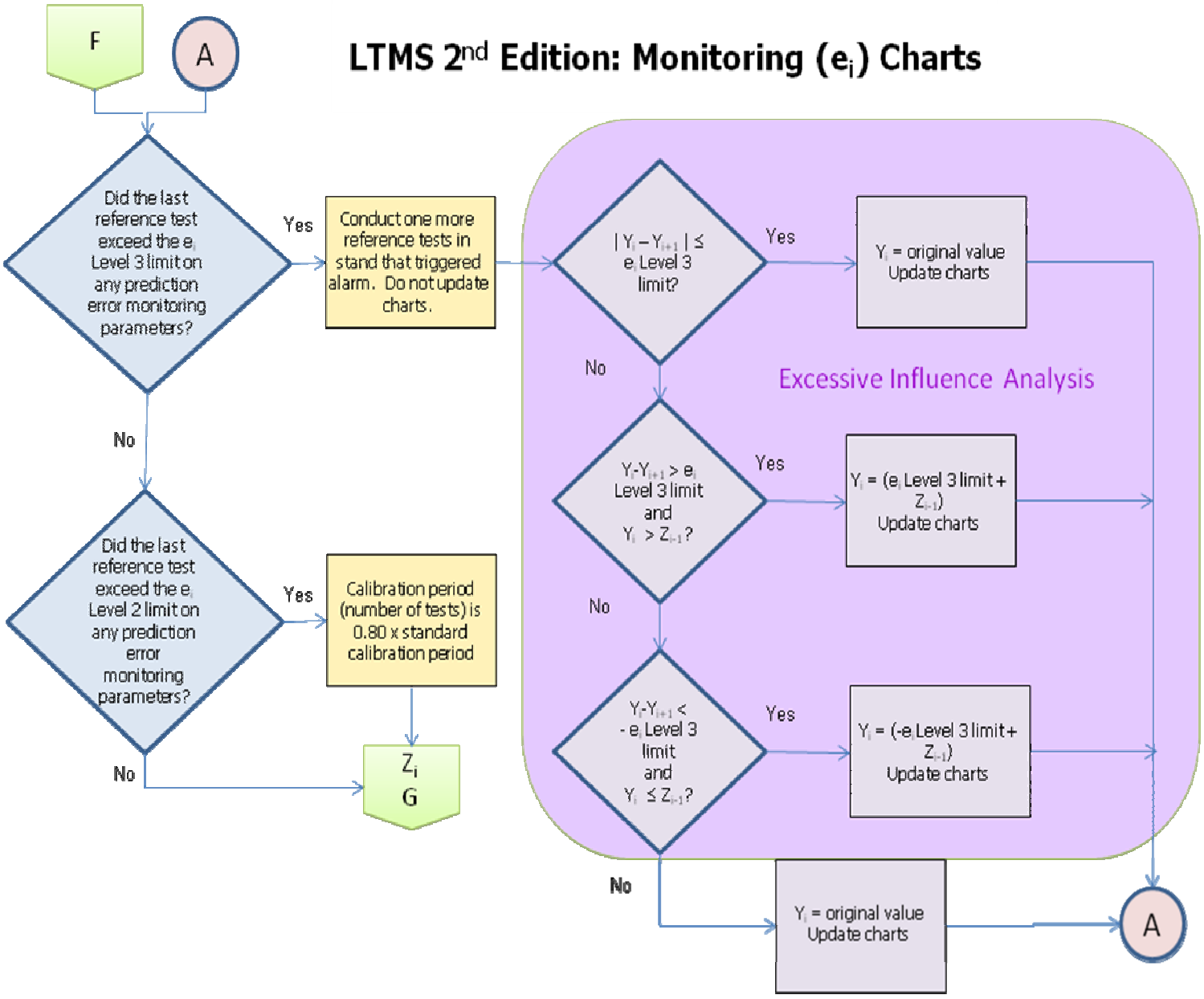
LTMS 2nd Edition Flowchart: Target Development



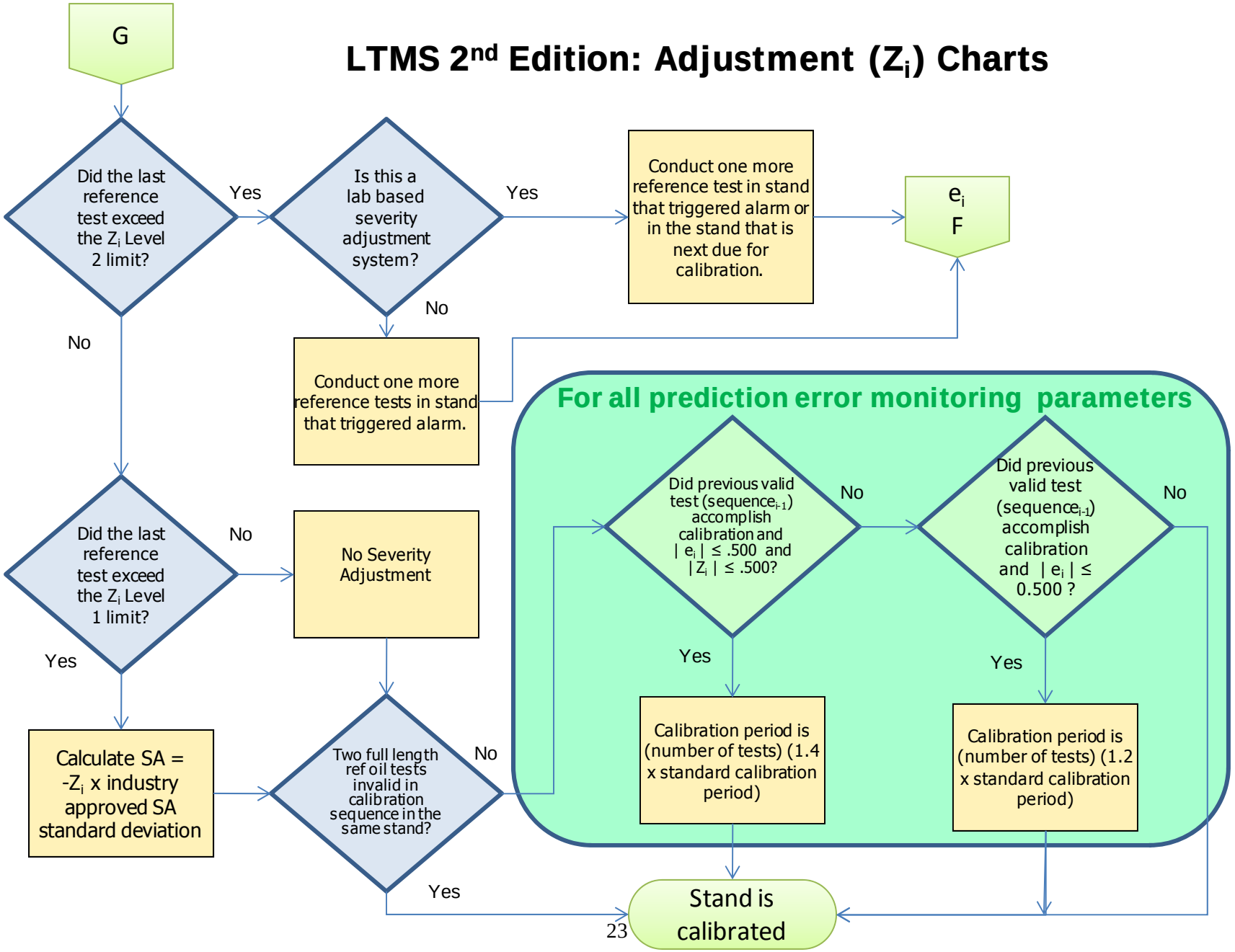

Reference Test
A
LTMS 2nd Edition Flowchart: Calibration
Lab based severity adjustment system?
No
This is a stand based severity adjustment system
Is this a new stand?
No
Status E
Yes
Yes
C
Is the test lab calibrated (existing lab)?
No
This is the first test stand in the lab
Run 3 valid reference or matrix tests in the stand uninterrupted by non-reference tests
Set Z_0 = Average of first 3 test results in the reference entity
e_i F
Yes
B
Is this a new stand in a lab?
Yes
Run one reference test
Did the reference test exceed the e_i Level 1 limit for any prediction error monitoring parameter?
No
No
Status E
Yes
D
Run one reference test

LTMS 2nd Edition Flowchart: Status




F
A
LTMS 2nd Edition: Monitoring (ei) Charts
Did the last reference test exceed the ei Level 3 limit on any prediction error monitoring parameters?
Yes
Conduct one more reference tests in stand that triggered alarm. Do not update charts.
No
Did the last reference test exceed the ei Level 2 limit on any prediction error monitoring parameters?
Yes
Calibration period (number of tests) is 0.80 x standard calibration period
No
Zi
G
| Yi – Yi+1 | ≤ ei Level 3 limit?
Yes
Yi = original value
Update charts
No
Excessive Influence Analysis
Yi-Yi+1 > ei Level 3 limit and Yi > Zi-1?
Yes
Yi = (ei Level 3 limit + Zi-1)
Update charts
No
Yi-Yi+1 < - ei Level 3 limit and Yi ≤ Zi-1?
Yes
Yi = (-ei Level 3 limit + Zi-1)
Update charts
No
Yi = original value
Update charts
A

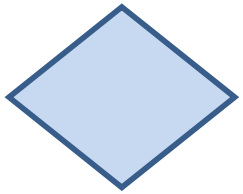
LTMS 2nd Edition: Adjustment (Z_i) Charts



Flowchart Symbol Legend

» Terminal Point: start, stop, interrupt, delay

» Process: Defined operation



» Decision: Switching operation that determines a number of alternative paths

» Offpage Connector: enter or exit from a page

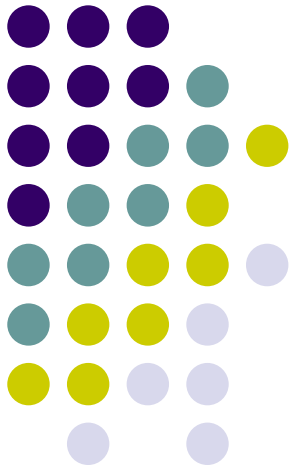
» Connector: Exit to, or entry from, another part of a page

Attachment 6

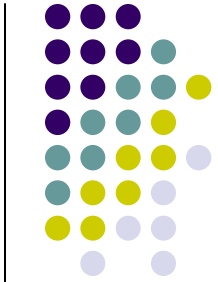
ISB LTMS 2nd Edition Example

Art Andrews

May 2010



LTMS 2nd Edition Choices



1. Choose primary parameters
2. Choose acceptance criteria for new stand
   - # of initial calibration tests (currently=2 for new lab, =1 for subsequent stands)
   - Use severity EWMA fast start?
3. Choose Severity EWMA (*Z*) limits
   - Intent is to set these at point where oil discrimination is lost, or unit conversion between physical units and standard deviation units breaks down (Chadwick Plots)
4. Choose reference entity: lab or stand
   - In this example, entity = lab
5. Other choices
   - SA's? lambda?

Primary Parameters

- ACSW - Average Cam Shaft Wear
- ATWL - Average Tappet Weight Loss

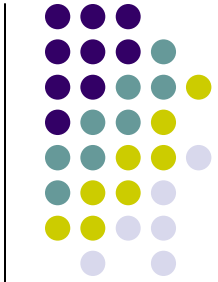
LUBRICANT TEST MONITORING SYSTEM CONSTANTS

		EWMA Chart				Shewhart Chart	
		LAMBDA		K		K	
Chart Level	Limit Type	Precision	Severity	Precision	Severity	Precision	Severity
Stand	Action	0.3	0.3	2.10	2.36	2.10	1.96
Industry	Warning	0.2	0.2	2.10	2.36	--	--
	Action	0.2	0.2	2.80	3.00	--	--

API CJ-4 Pass/Fail Limits

Cummins ISB		
Tappet Wear, max	mg	100
Cam Wear, max	microns	55
Crosshead Weight Loss	mg	Rate & Report

Alarms and Severity Adjustments



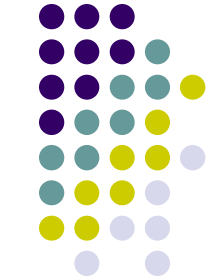
Current LTMS 1st Ed.

- Shewhart severity alarm is the only alarm that triggers additional reference test
- No severity adjustments are in place
- lambda = 0.3

2nd Ed.

- Includes no Shewhart severity alarm
- Relies on *e* alarms
- Option to include EWMA severity alarm
- Continuous severity adjustments
- lambda = 0.3

New Stand Acceptance Criteria



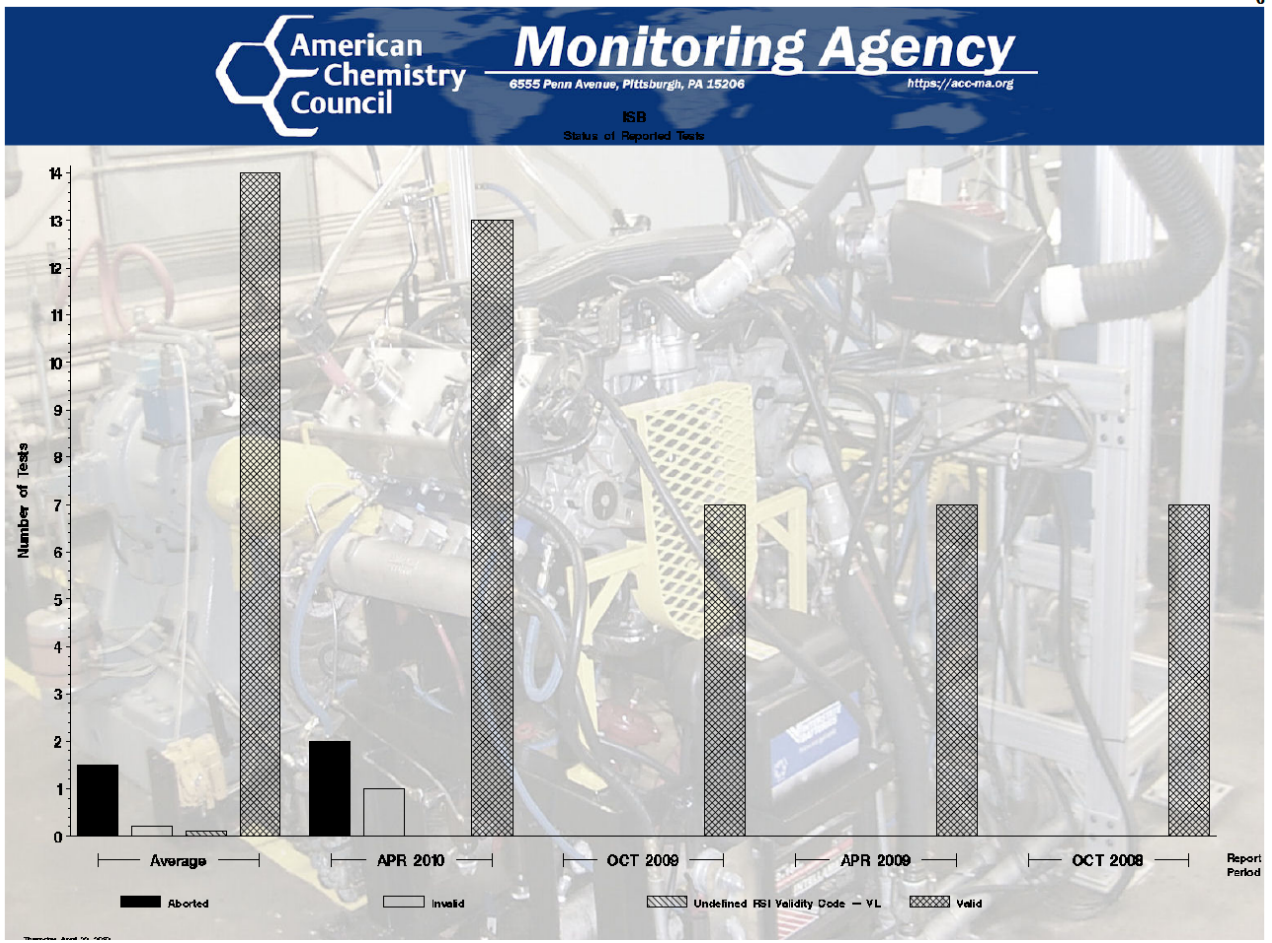
- LTMS 2nd Edition recommends 3 acceptable reference oil resuts for lab acceptance, and employs “fast start” principle for severity EWMA
  - Is this agreeable for ISB?

- This ISB LTMS 2nd edition example includes fast start for Z_0

TMC and ACC Reports

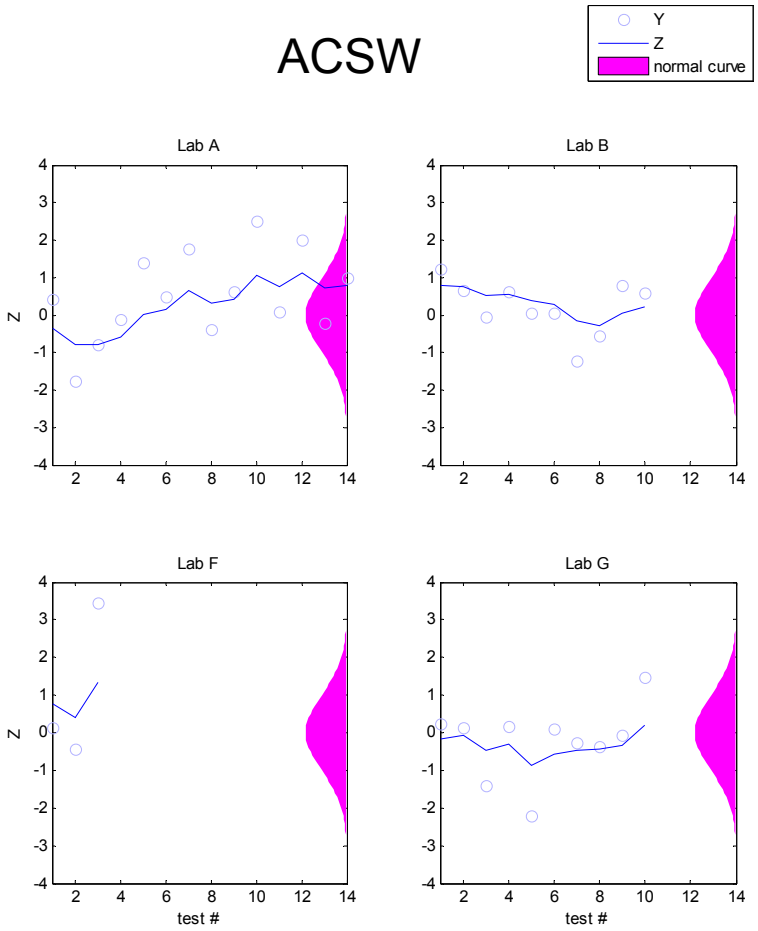
ISB - Report Period: APR 2010
Status Of Reported Tests

STATUS	COUNT	PERCENT
Aborted	2	12.50
Invalid	1	6.25
Valid	13	81.25
Total Reported Tests	16	100.00

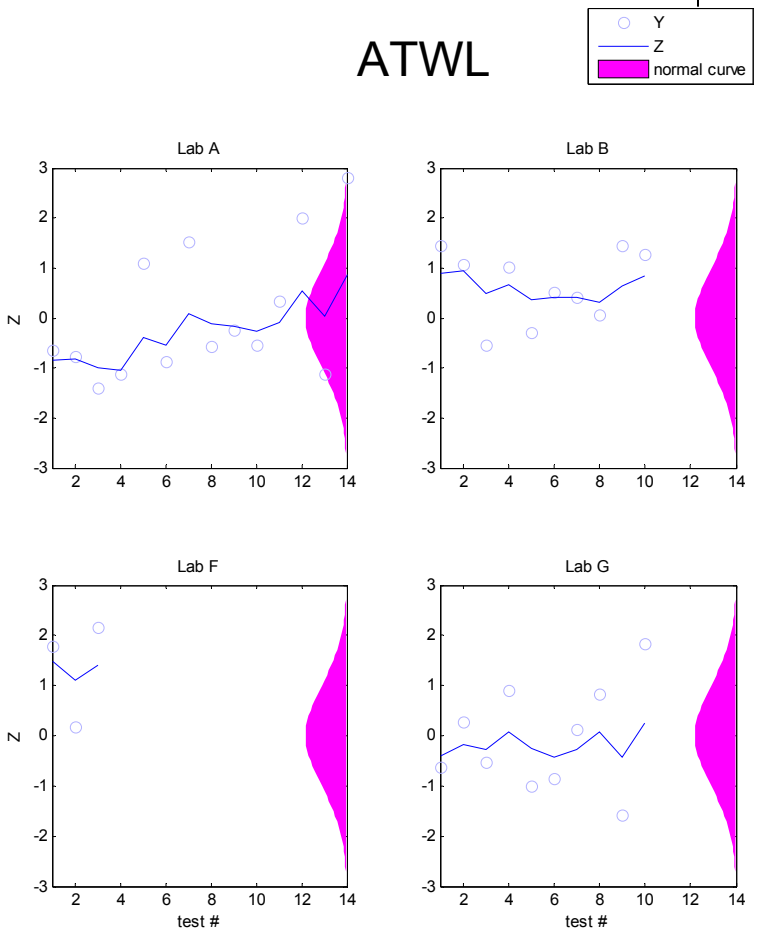


Severity Charts

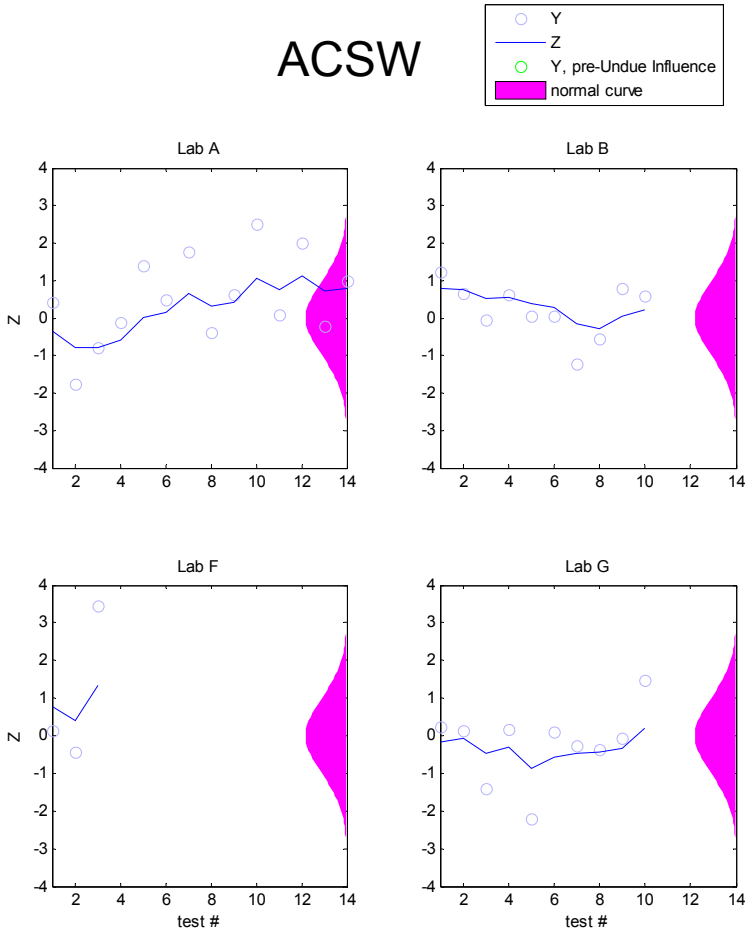
ACSW

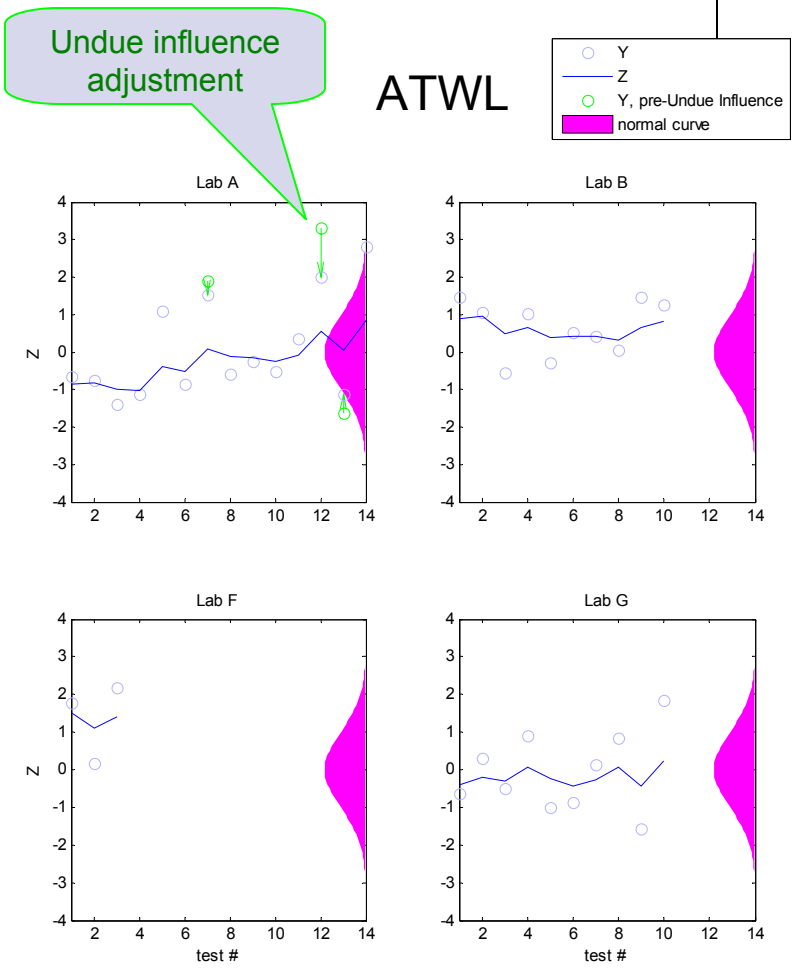


ATWL



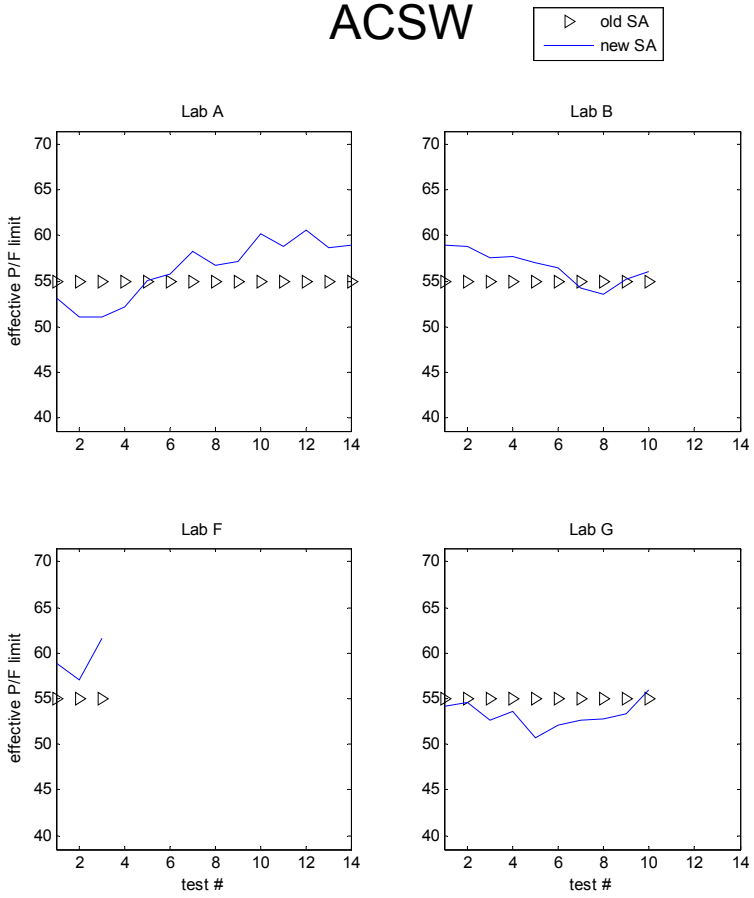
Severity Charts with Undue Influence



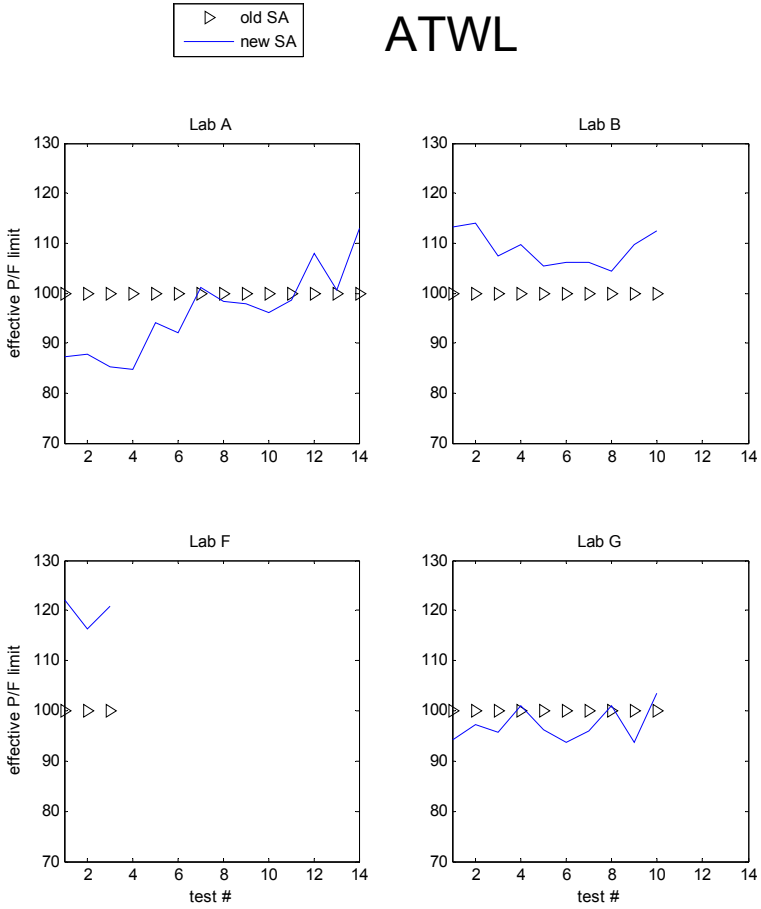


Effective Pass/Fail Limits

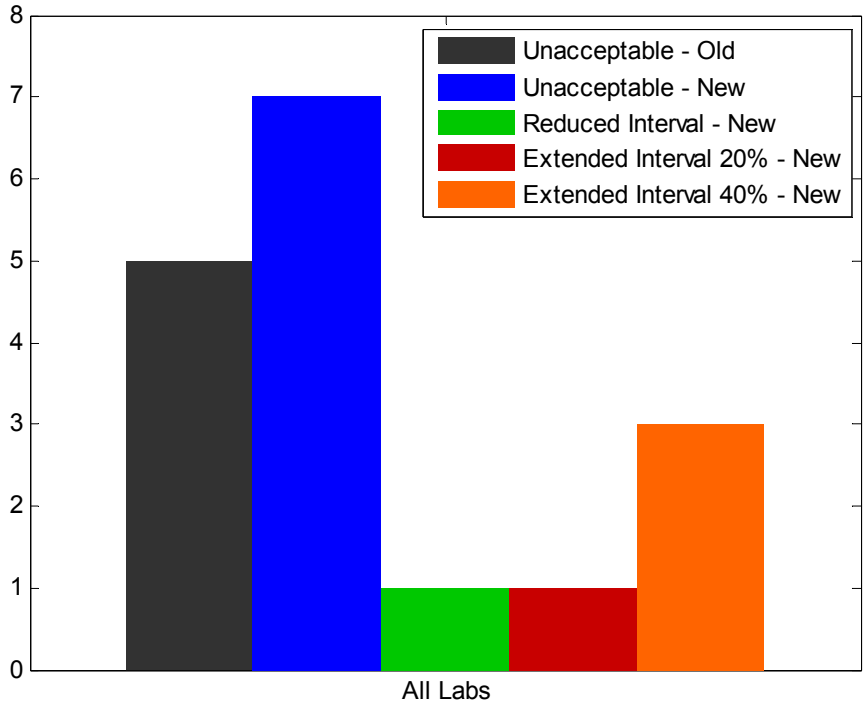
ACSW



ATWL

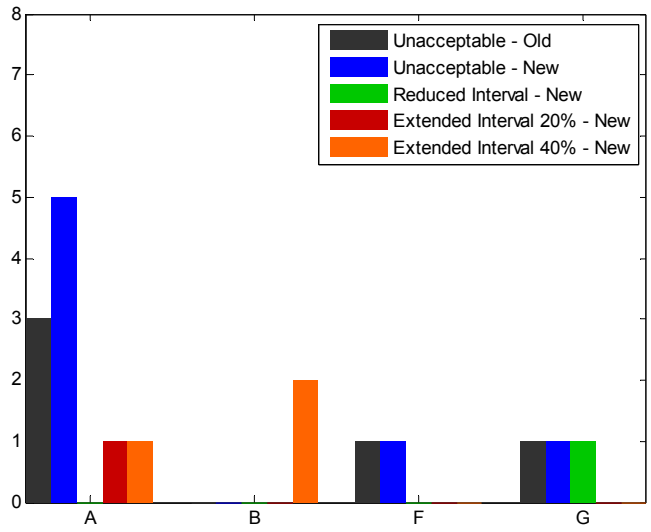


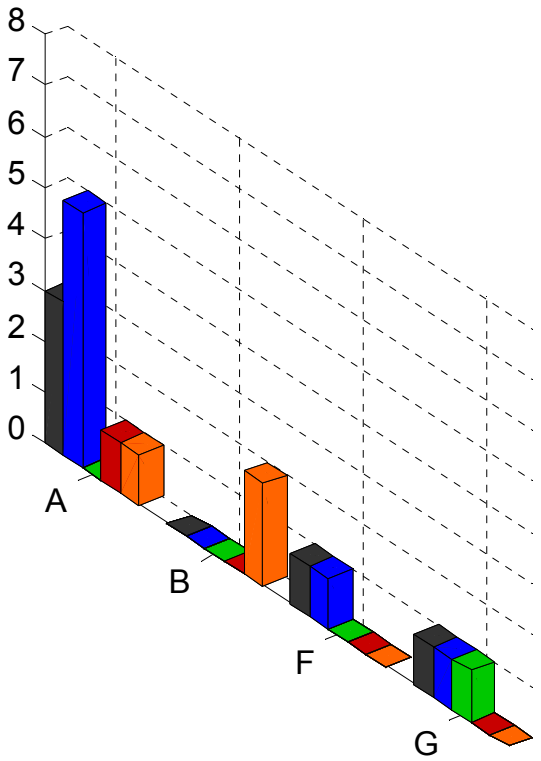
Alarms – All Engine Stands



* using LTMS 2nd Edition default limits

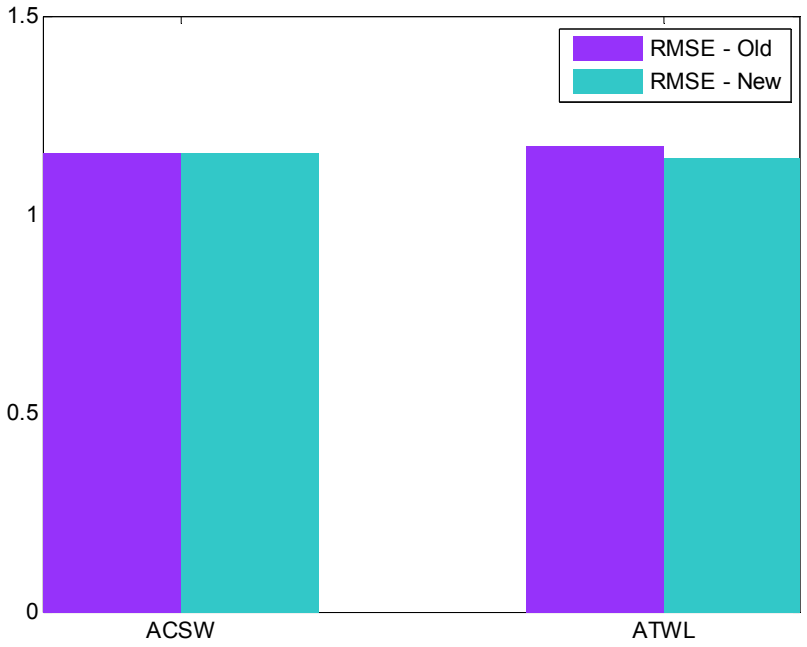
Alarms by Lab





rotated view

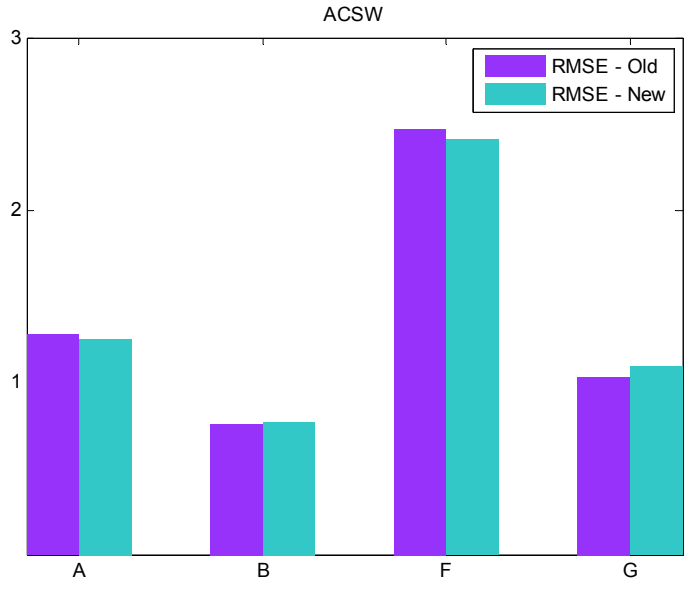
Prediction Error - All Labs

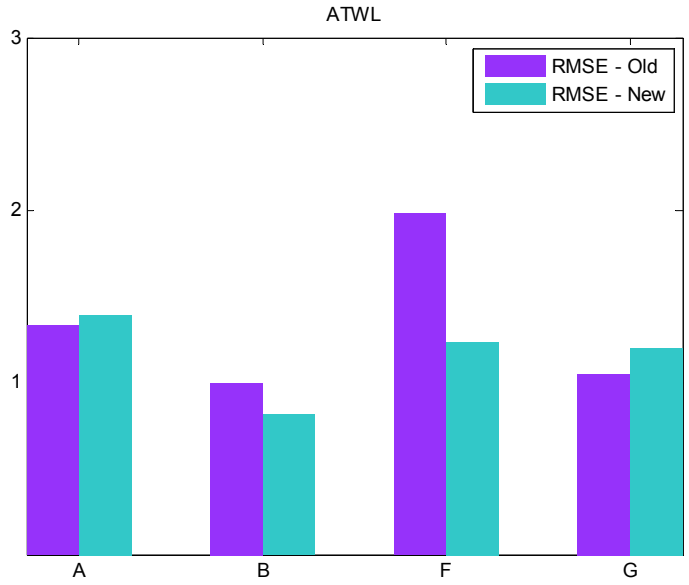


LTMS 2nd Edition can account for engine bias. However, historical ISB stands showed little bias ($Z \approx 0$).

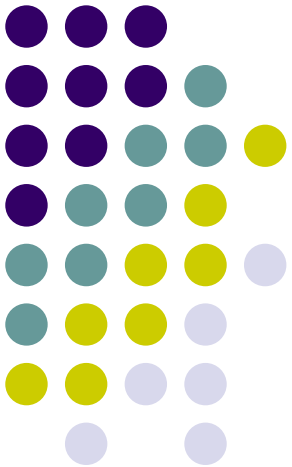
Therefore 1st and 2nd edition systems produce similar prediction error.

Prediction Error by Lab

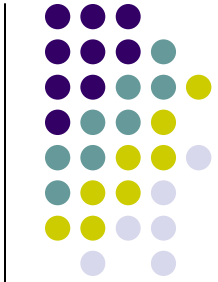




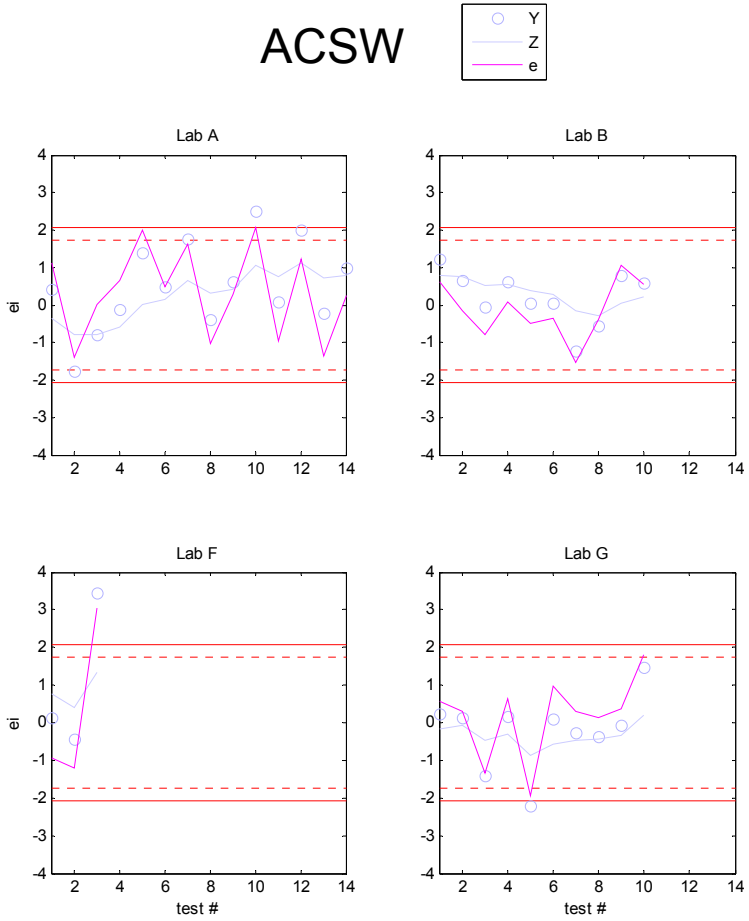
Backup Slides



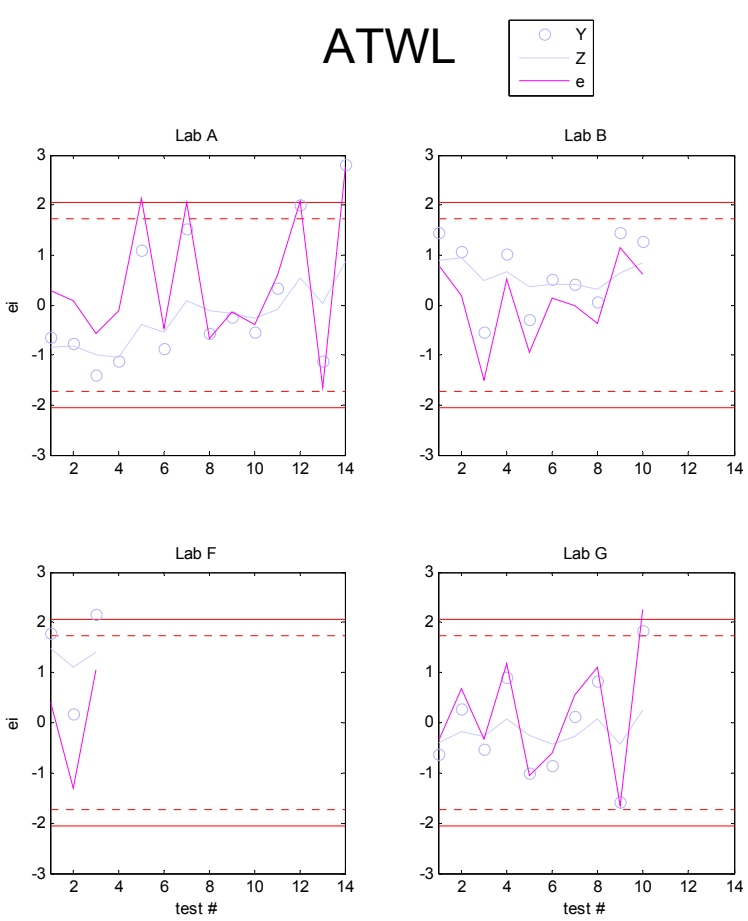
Residual (e) Charts



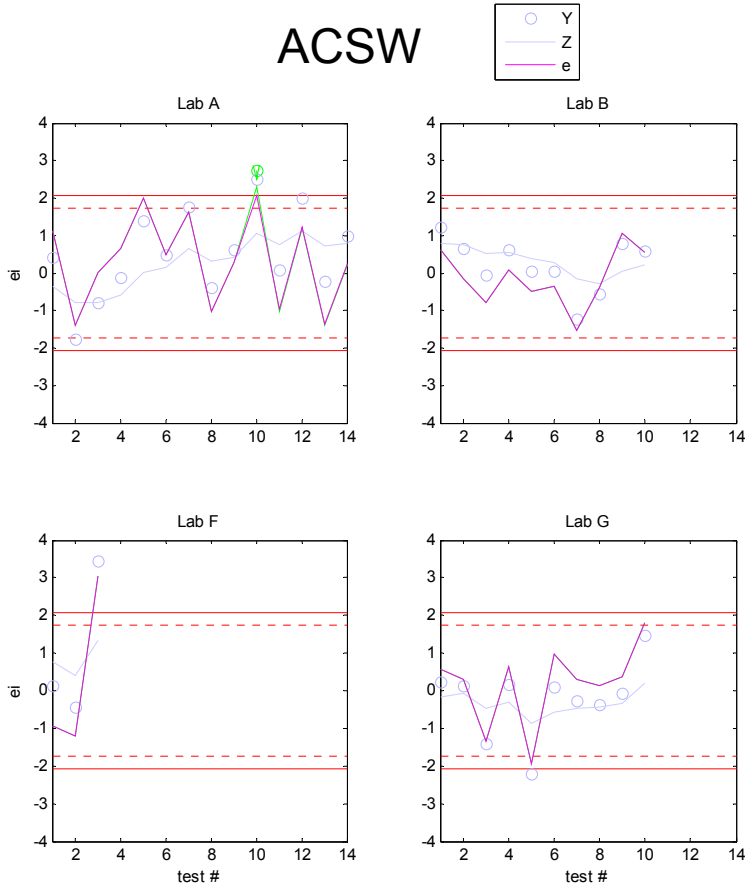
ACSW

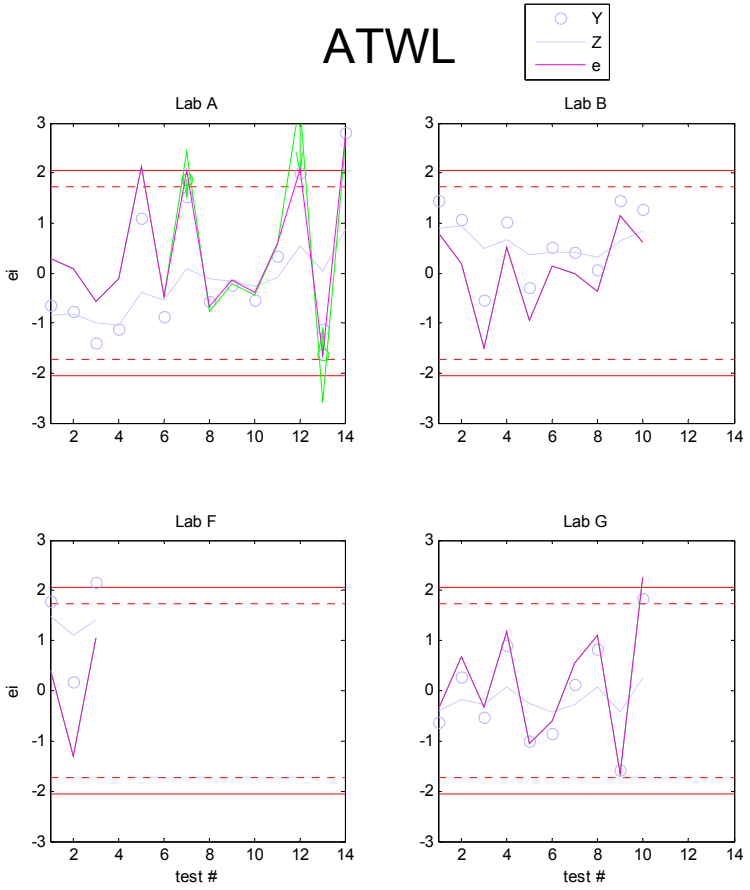


ATWL

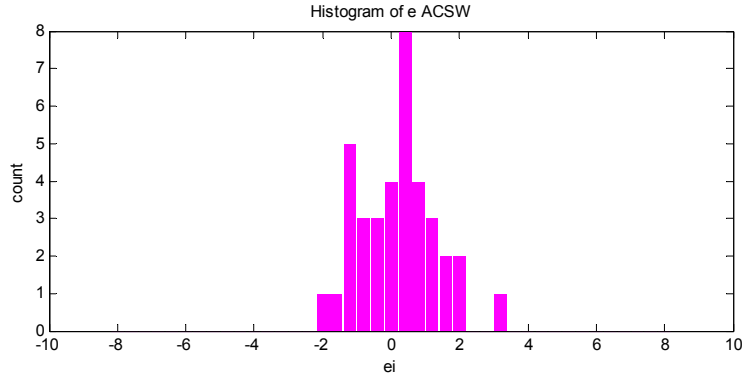


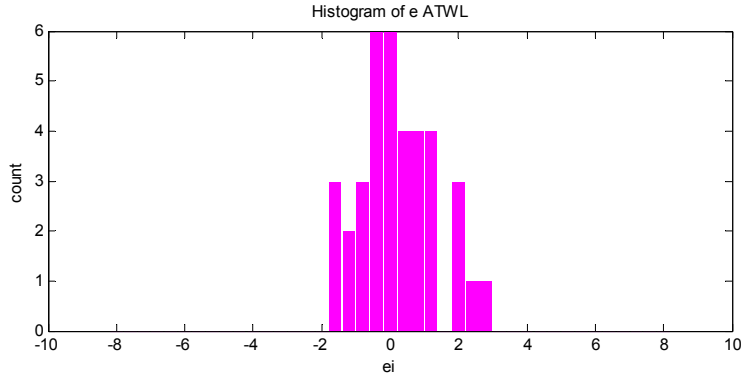
Residuals- with and without UI

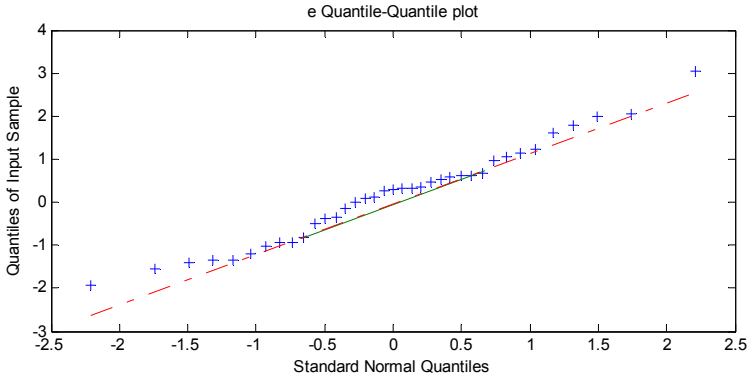


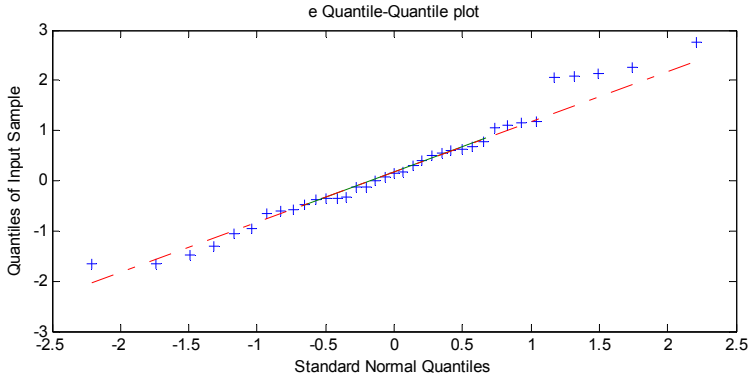


Tests for *e* Normality

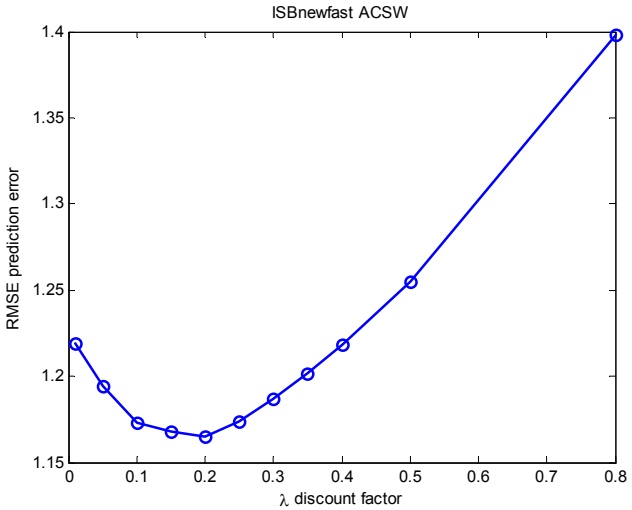


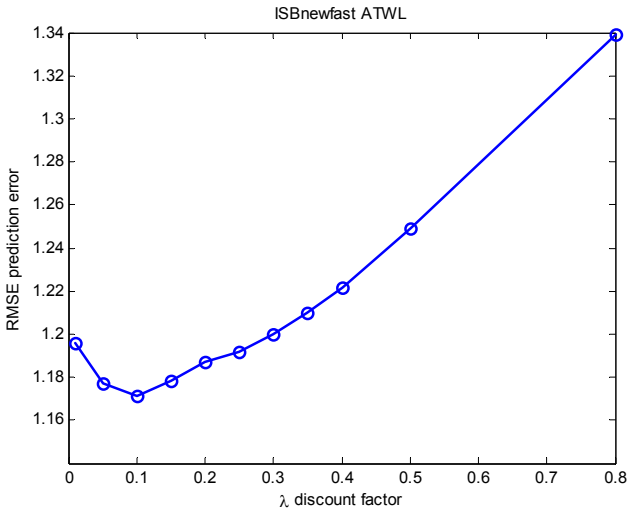






Lambda Optimization



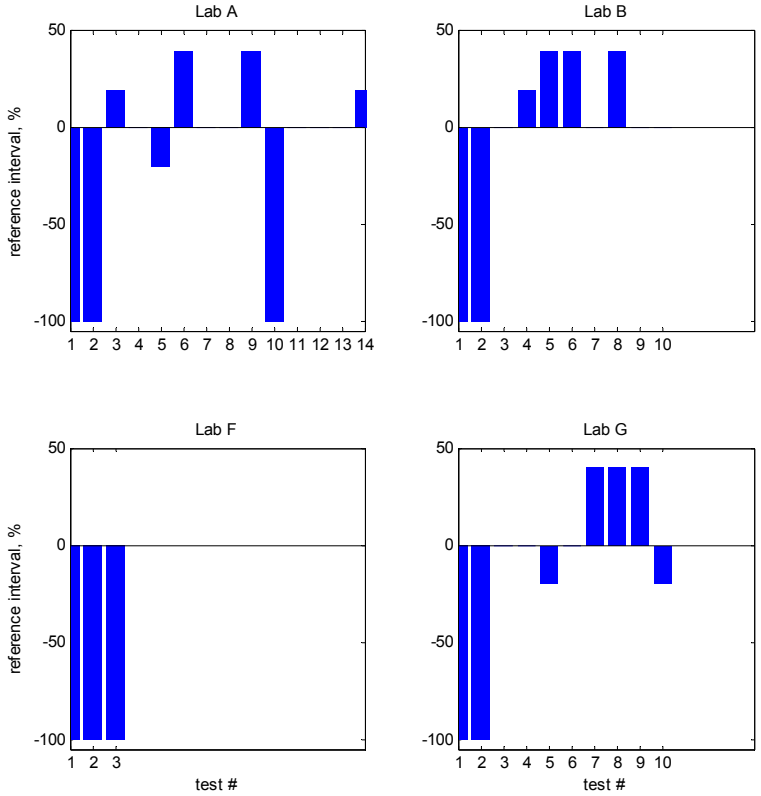


- LTMS 2nd Edition default $\lambda = 0.2$
- ISB LTMS 1st Edition $\lambda = 0.3$
- These plots indicate optimal $\lambda \approx 0.2$, however this is subject to some uncertainty

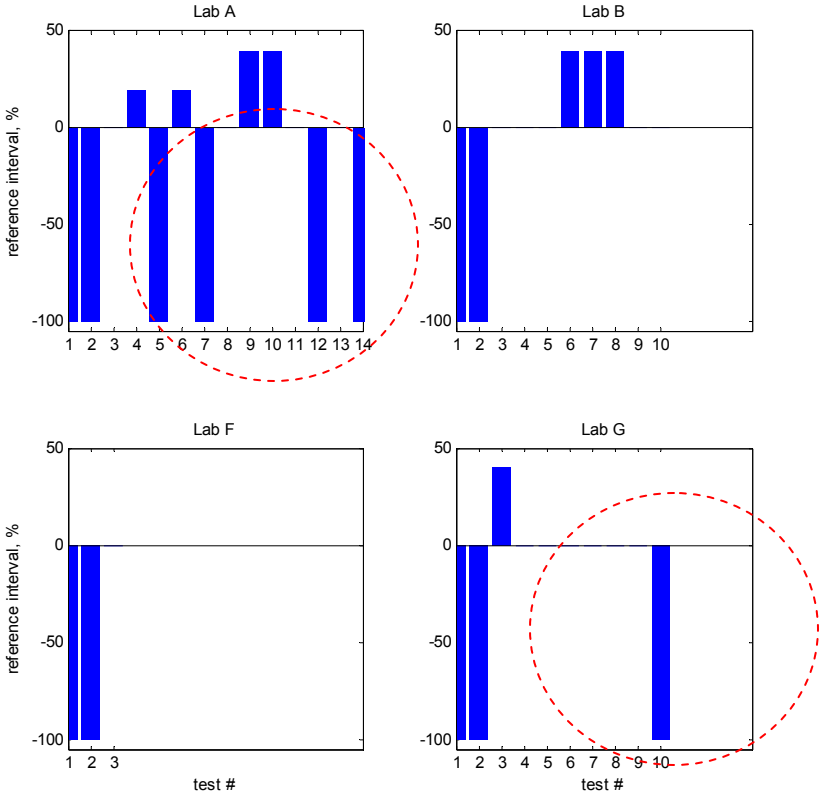
Reference Intervals

+40%, +20%, -20%, -100% (immediate re-reference)

ACSW



ATWL



ATWL produced more alarms than ACSW

Attachment 7

Cummins ISB
LTMS v2 Study

Art Andrews

September 21, 2010

Summary

- This document contains charts for
  - A simulated LTMS1-like lab-based system
  - A simulated LTMS2 lab-based system with a set of limits proposed during Heavy Duty Surveillance Panel Meeting 9/21/2010.
  - All charts based on historical ISB reference oil data from TMC
- There are a number of different charts contained
  - Severity charts (Y and Z)
  - Severity charts showing Excessive Influence calculation (Y and Z, where Y is shown both before and after Excessive Influence calculation)
  - Precision charts (Y, Z, and e)
- This document also contains figures comparing the RMSE (root mean square error) and Calibration Status statistics of the simulated LTMS1 and LTMS2 systems
- The author has attempted to use the notation and language contained in *ltms2ndEditionDraft17.7 (abridged) 20100920_markup.docx* draft of LTMS2 document.

LTMS v1
simulated lab-based system

lambda=0.2;

No Fast start

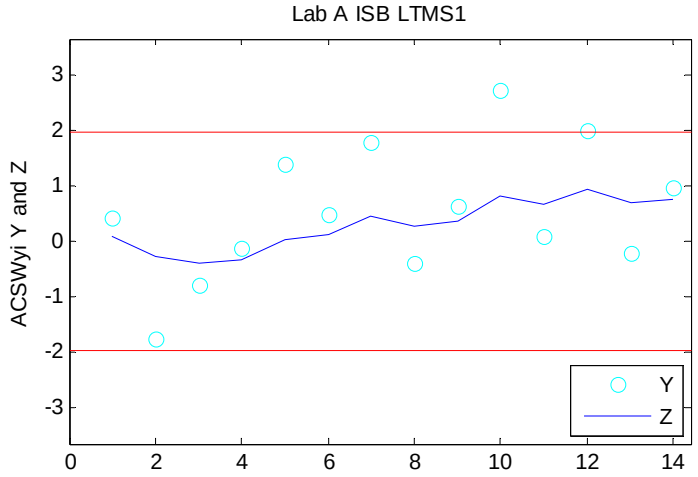
No e alarms

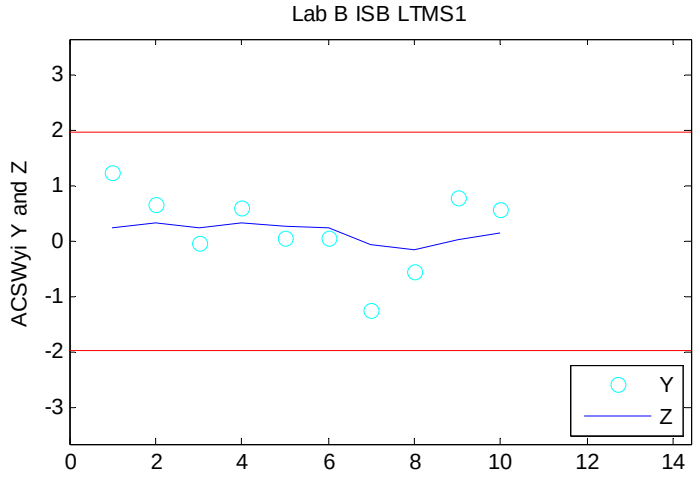
No Z alarms

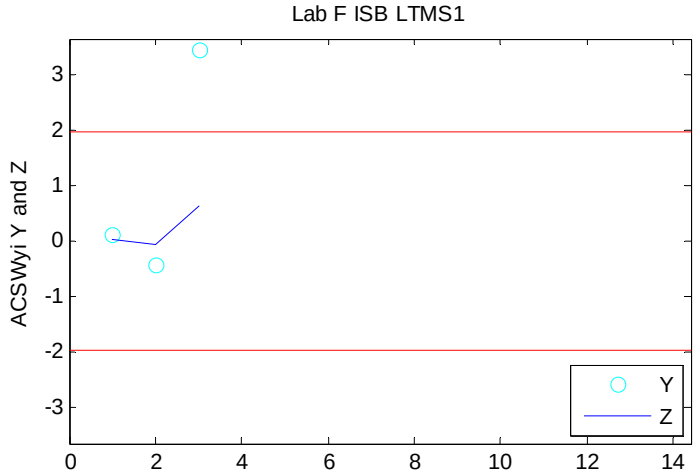
Shewhart severity (Y) limit = +/-1.96;

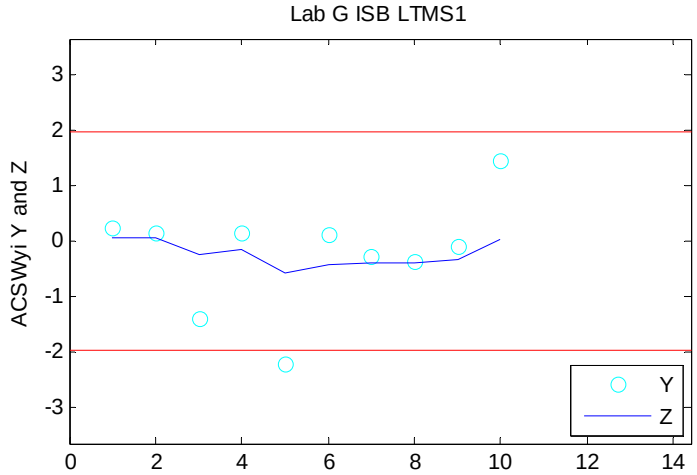
No Excessive Influence calculation

Cam wear severity charts

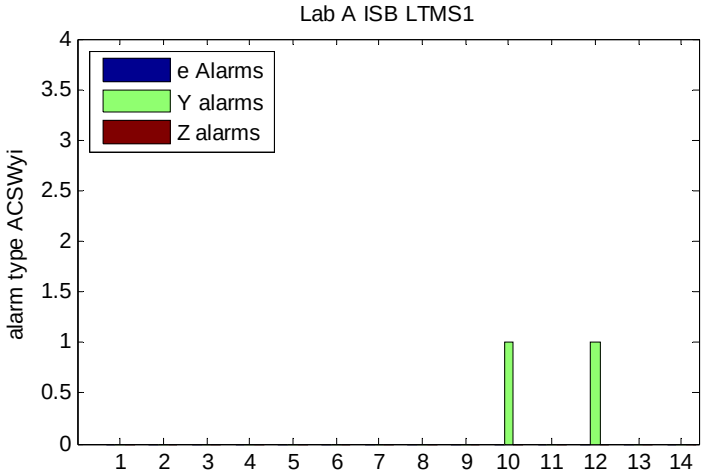


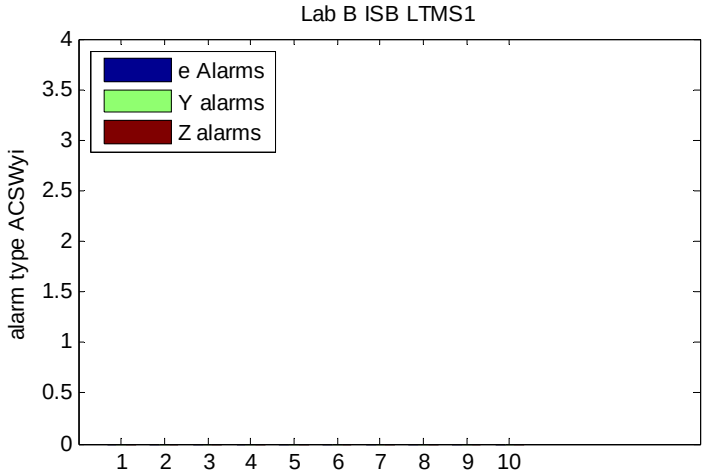


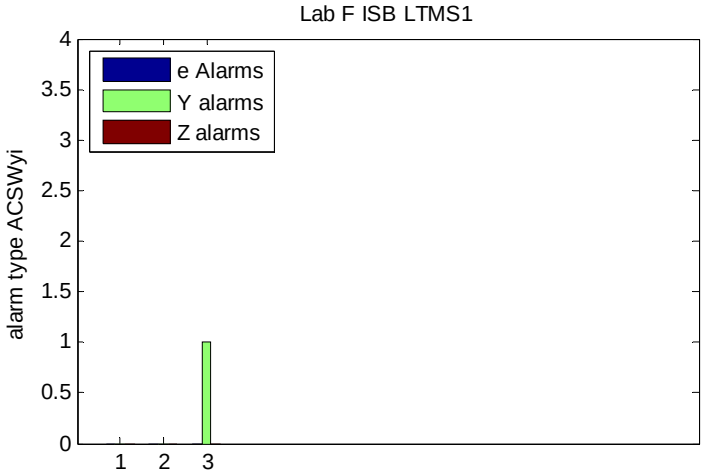


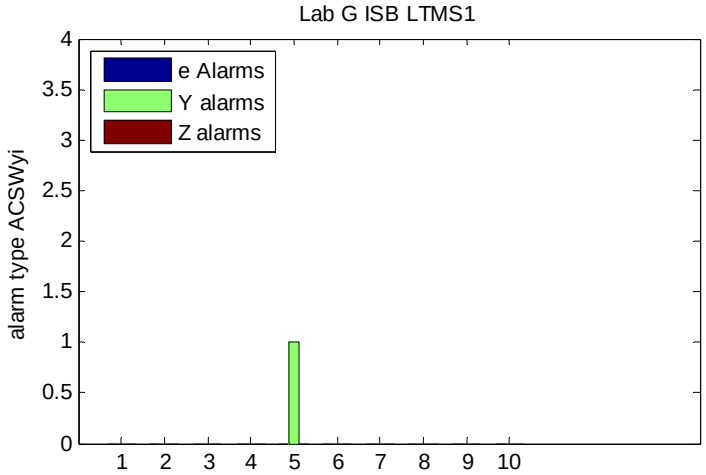


Cam wear alarms

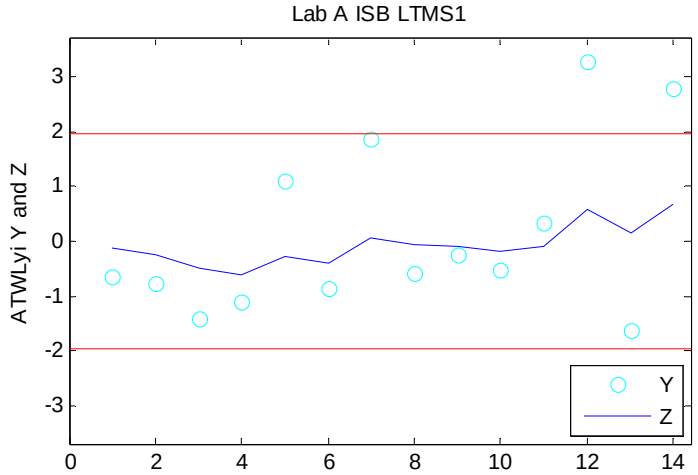


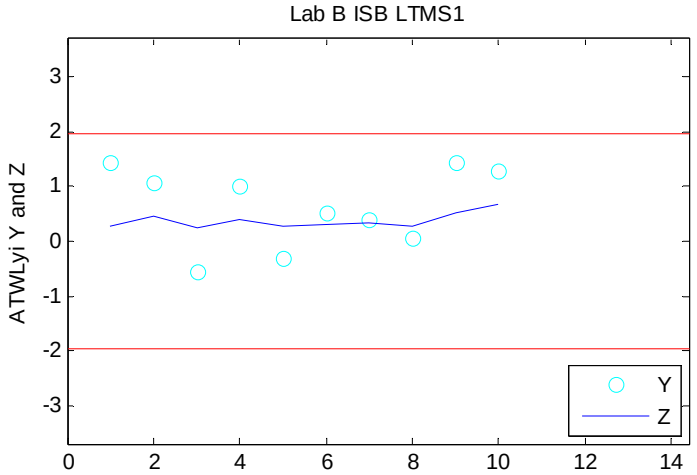


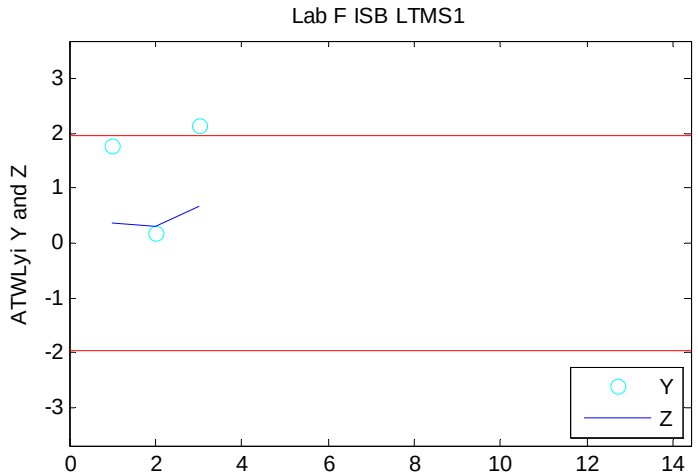


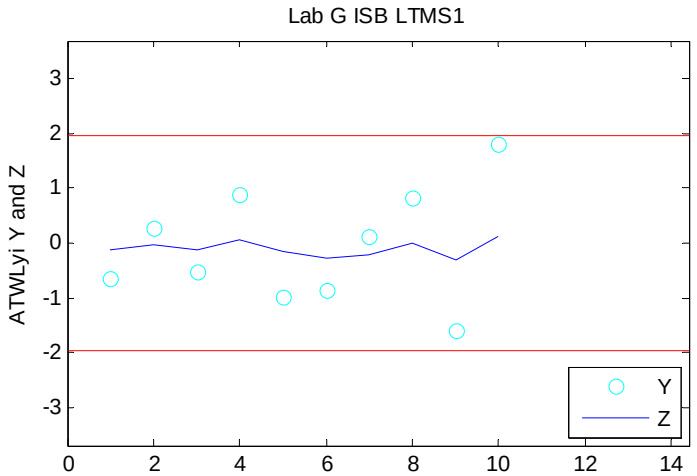


Tapper weight loss severity charts

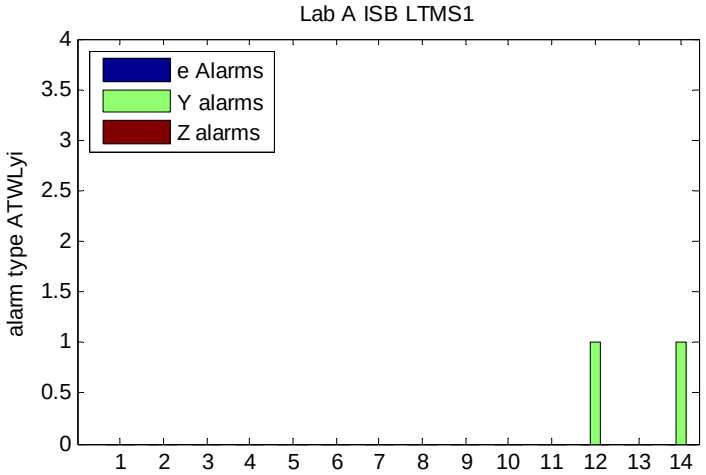


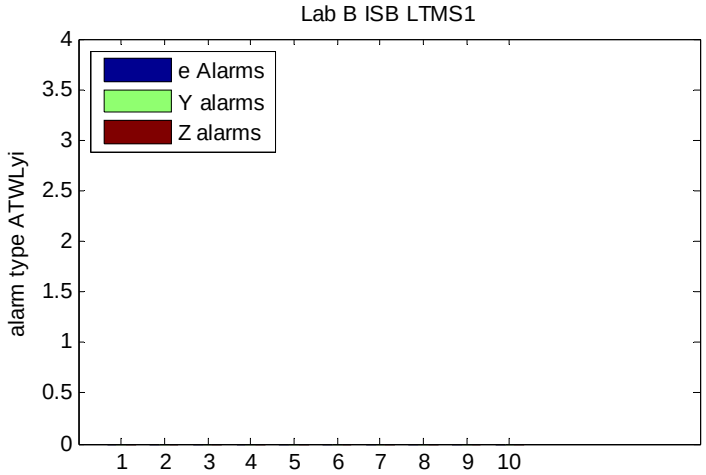


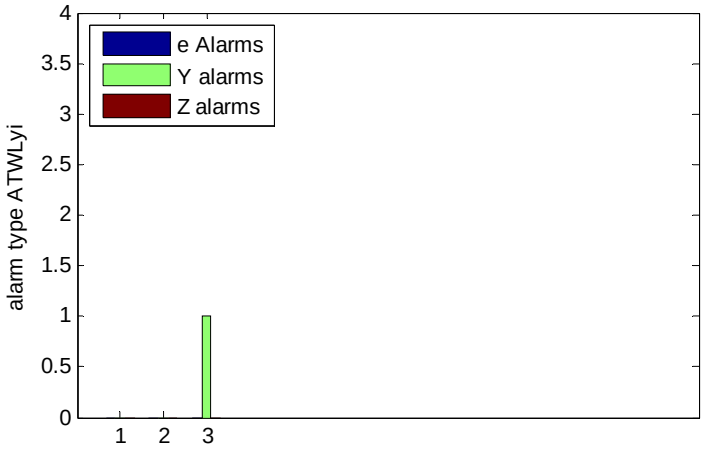


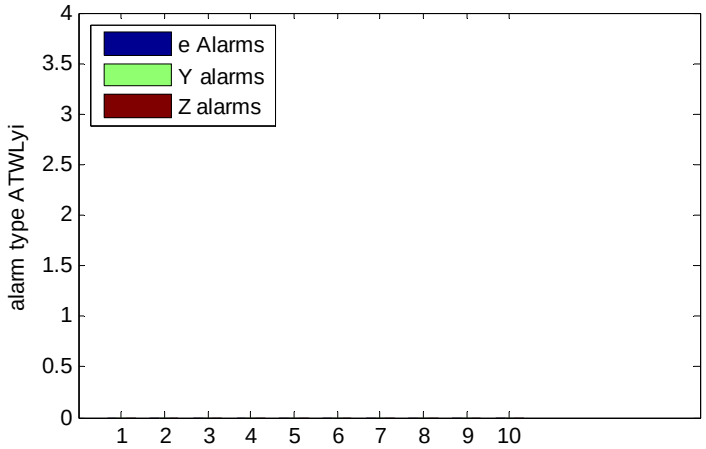


Tapper weight loss alarms









LTMS v2
proposed limits

lambda=0.2;

Fast start with three reference oil results

Level 1 e limit = 1.351;

Level 2 e limit = 1.734;

Level 3 e limit = 2.066;

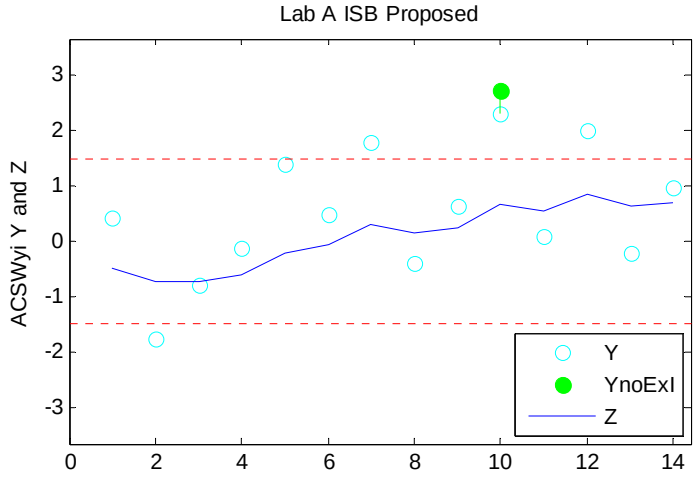
Level 1 Z limit = 0;

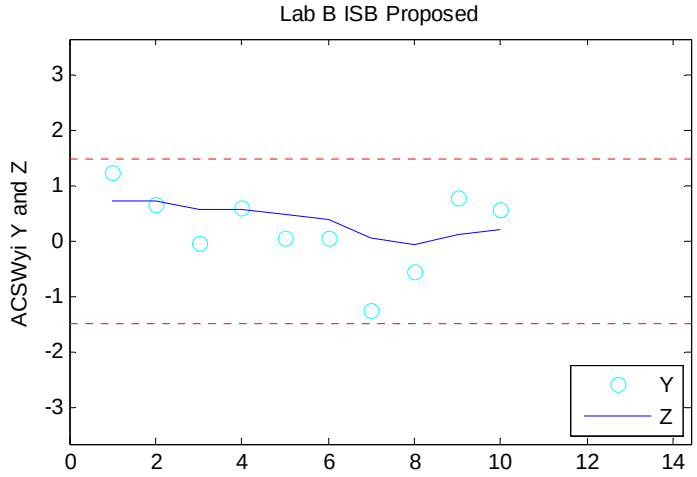
Level 2 Z limit = +/- 1.5;

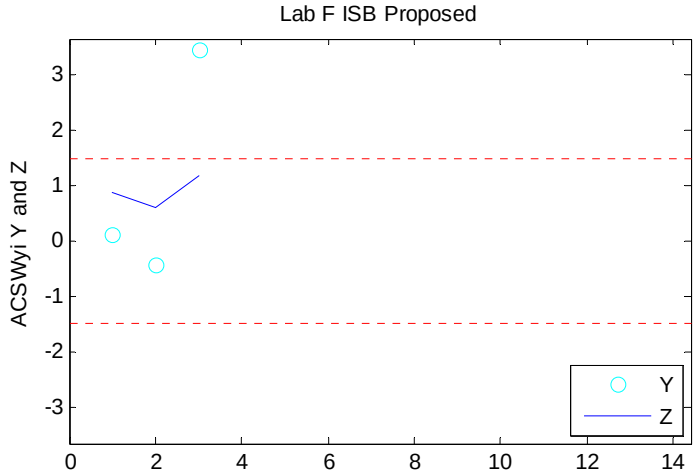
Ee=0.5;

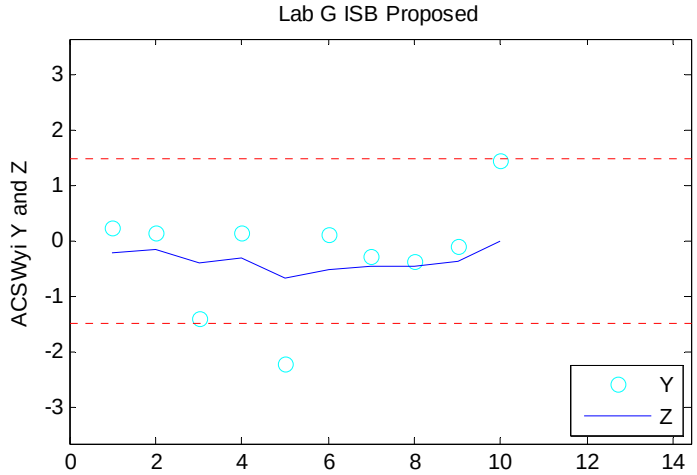
Ez=0.5;

Cam wear severity charts showing Excessive Influence (green circle)

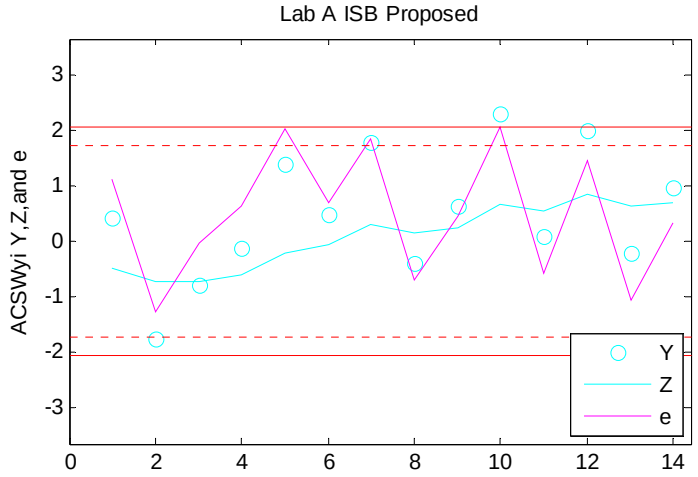


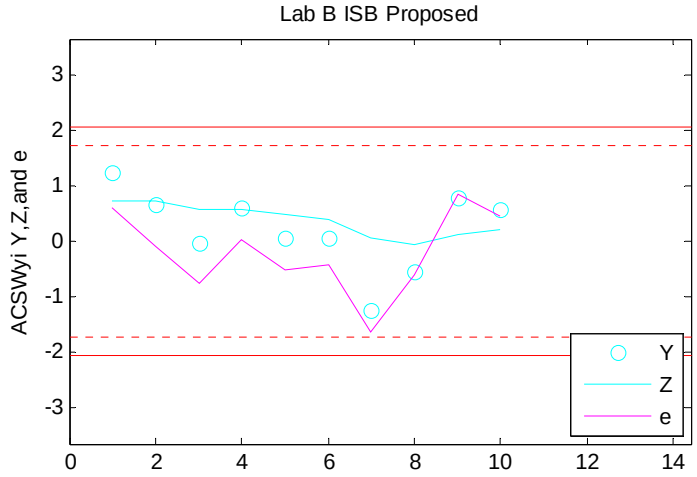


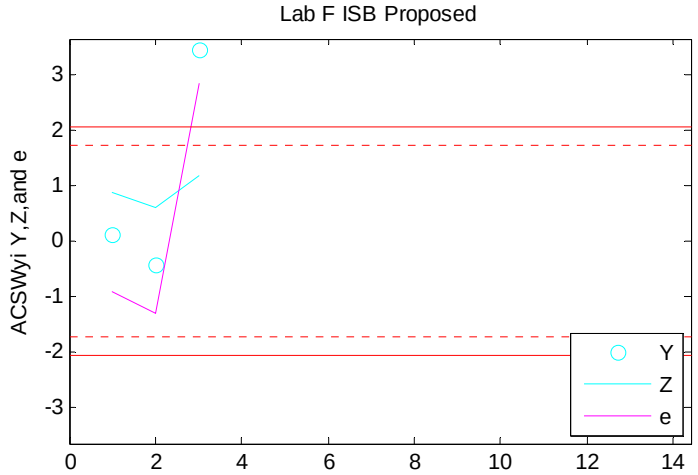


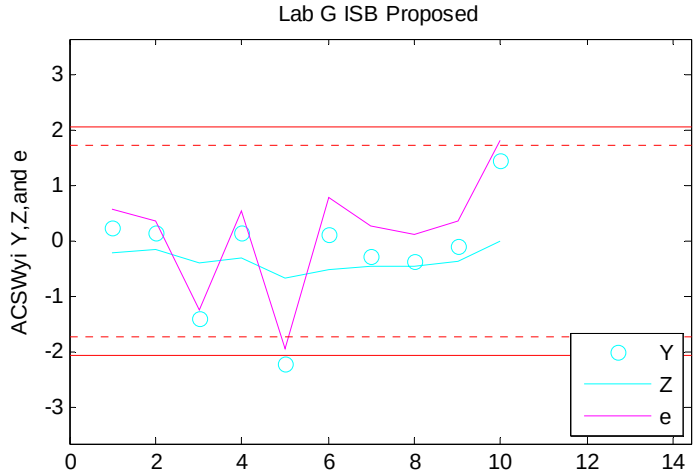


Cam wear precision charts showing e

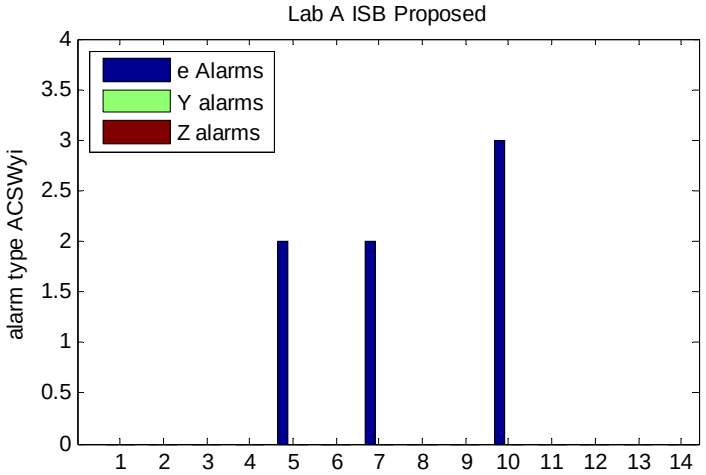


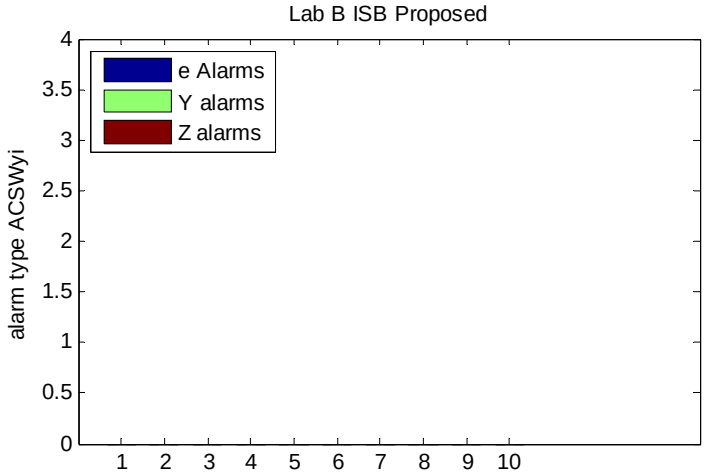


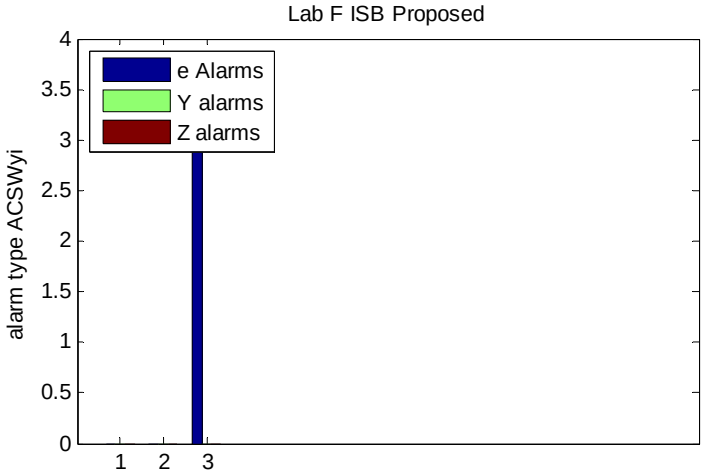


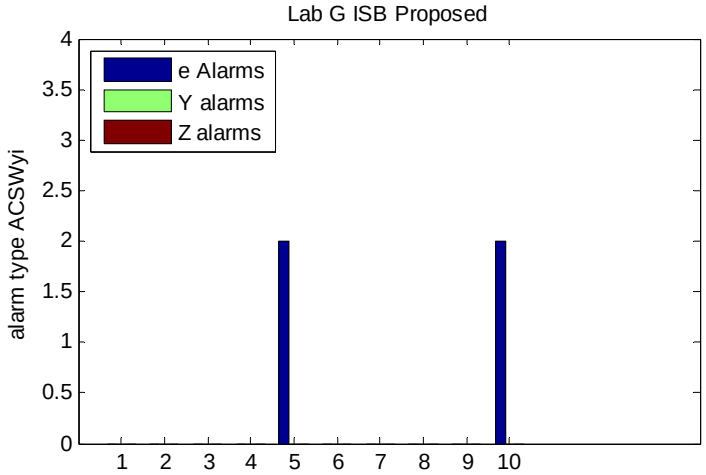


Cam wear alarms

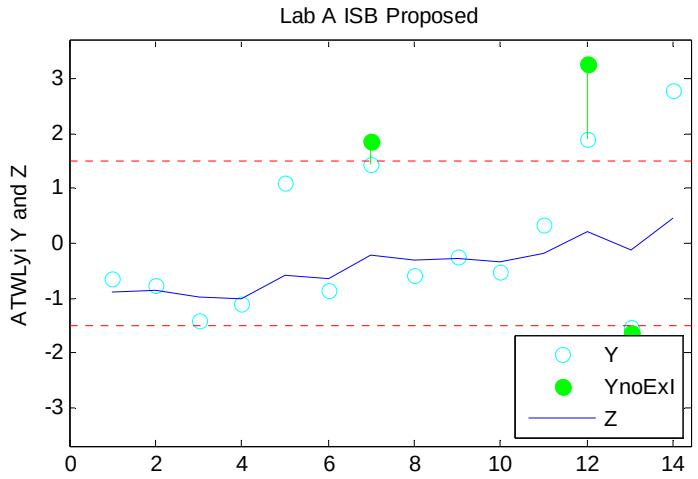


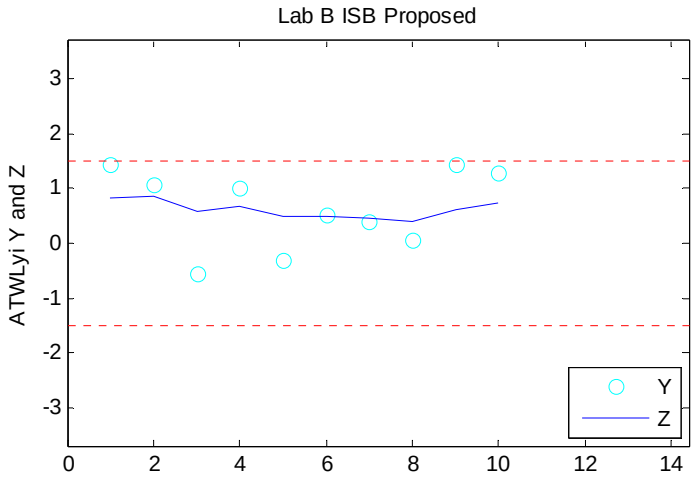


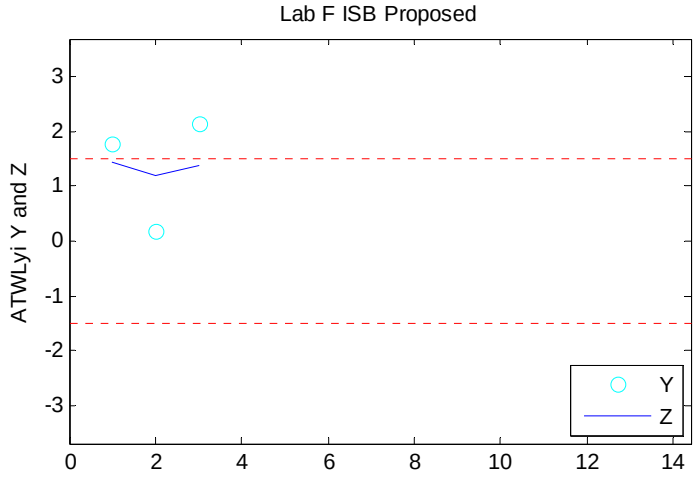


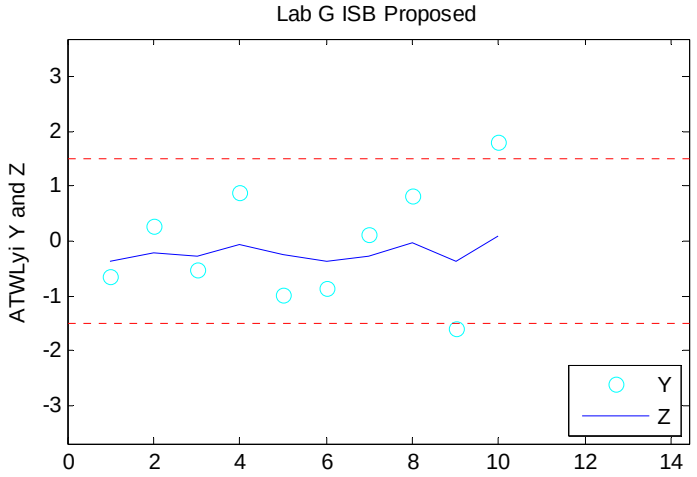


Tapper weight loss severity charts showing Excessive Influence calculation

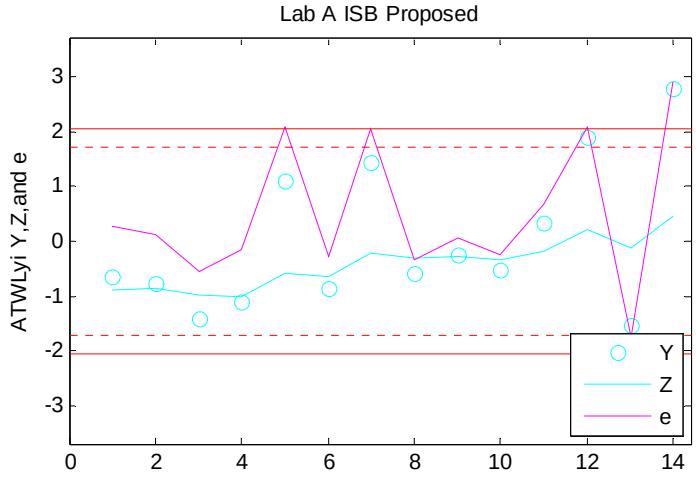


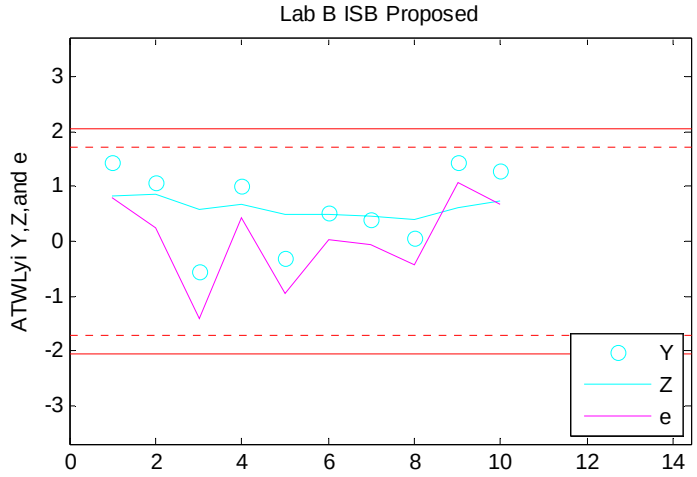


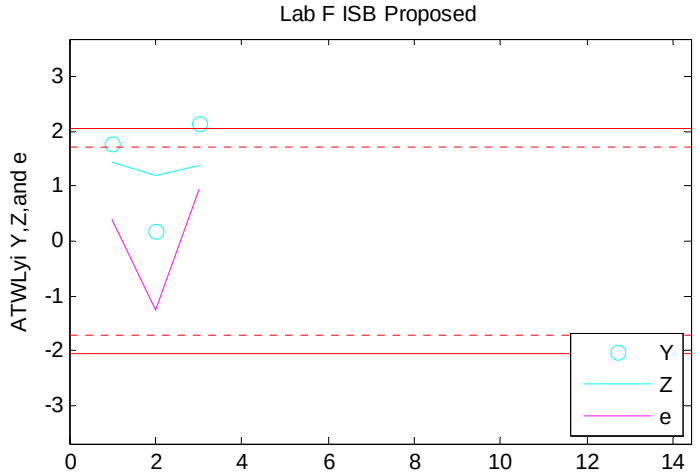




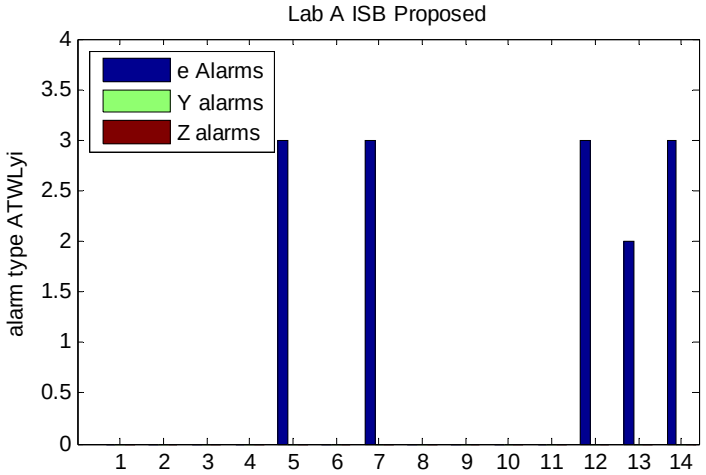
Tapper weight loss precision charts showing e

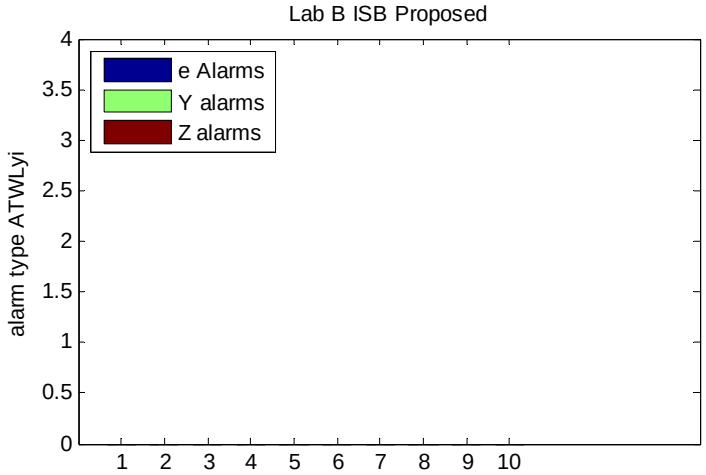


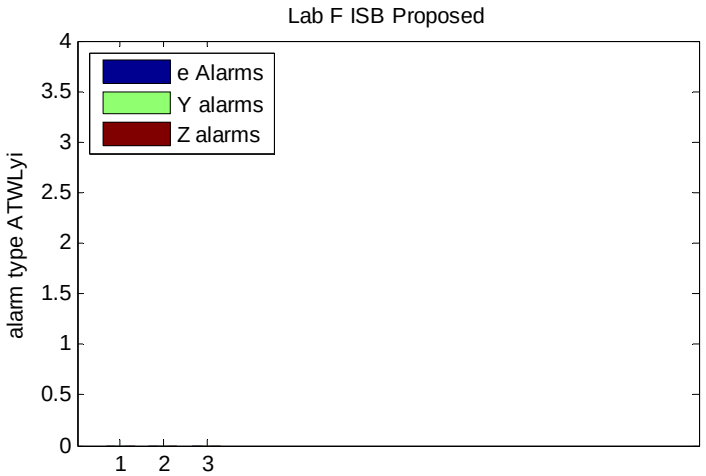


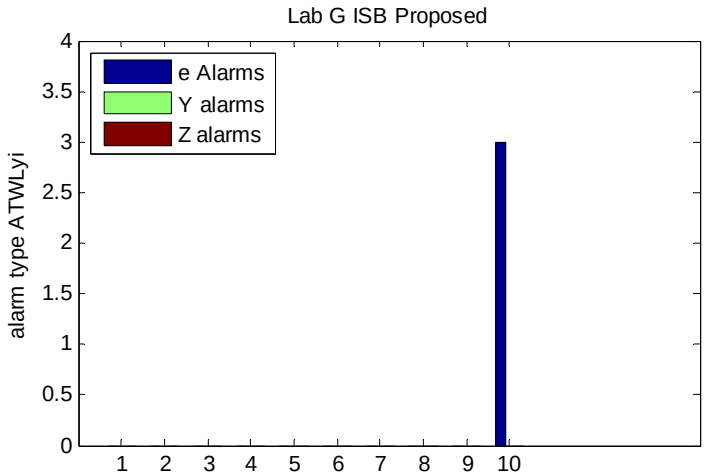


Tapper weight loss alarms



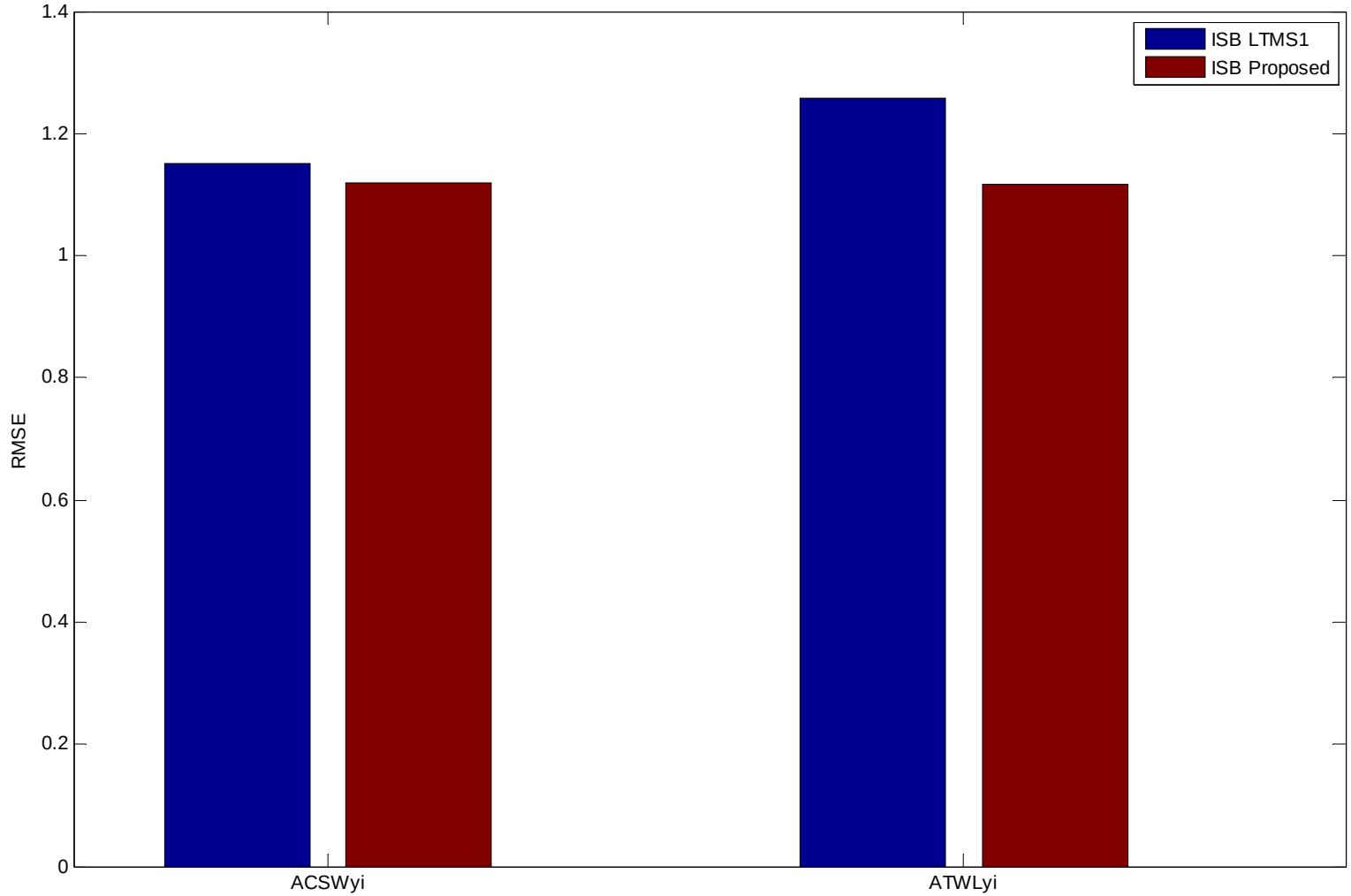


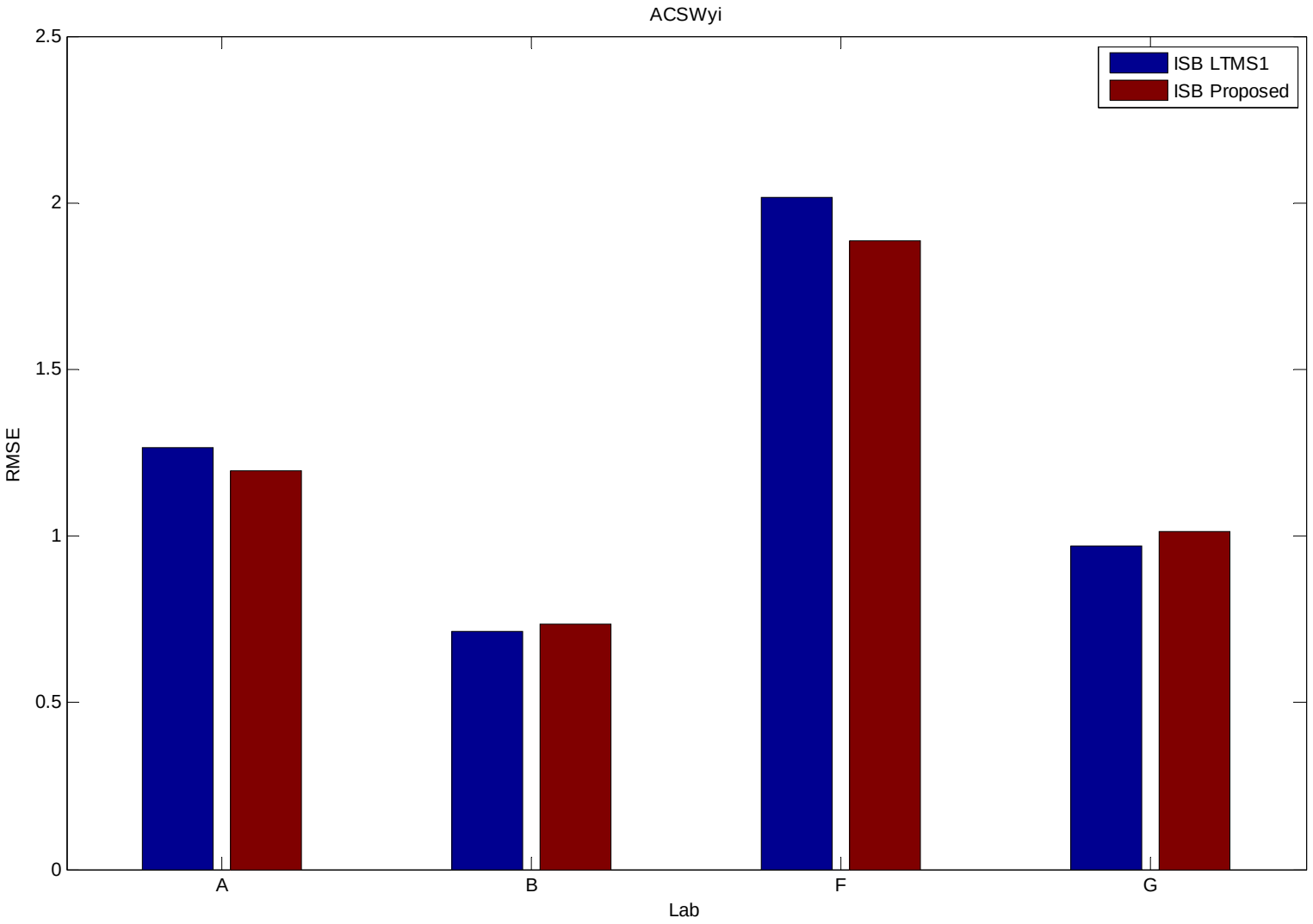


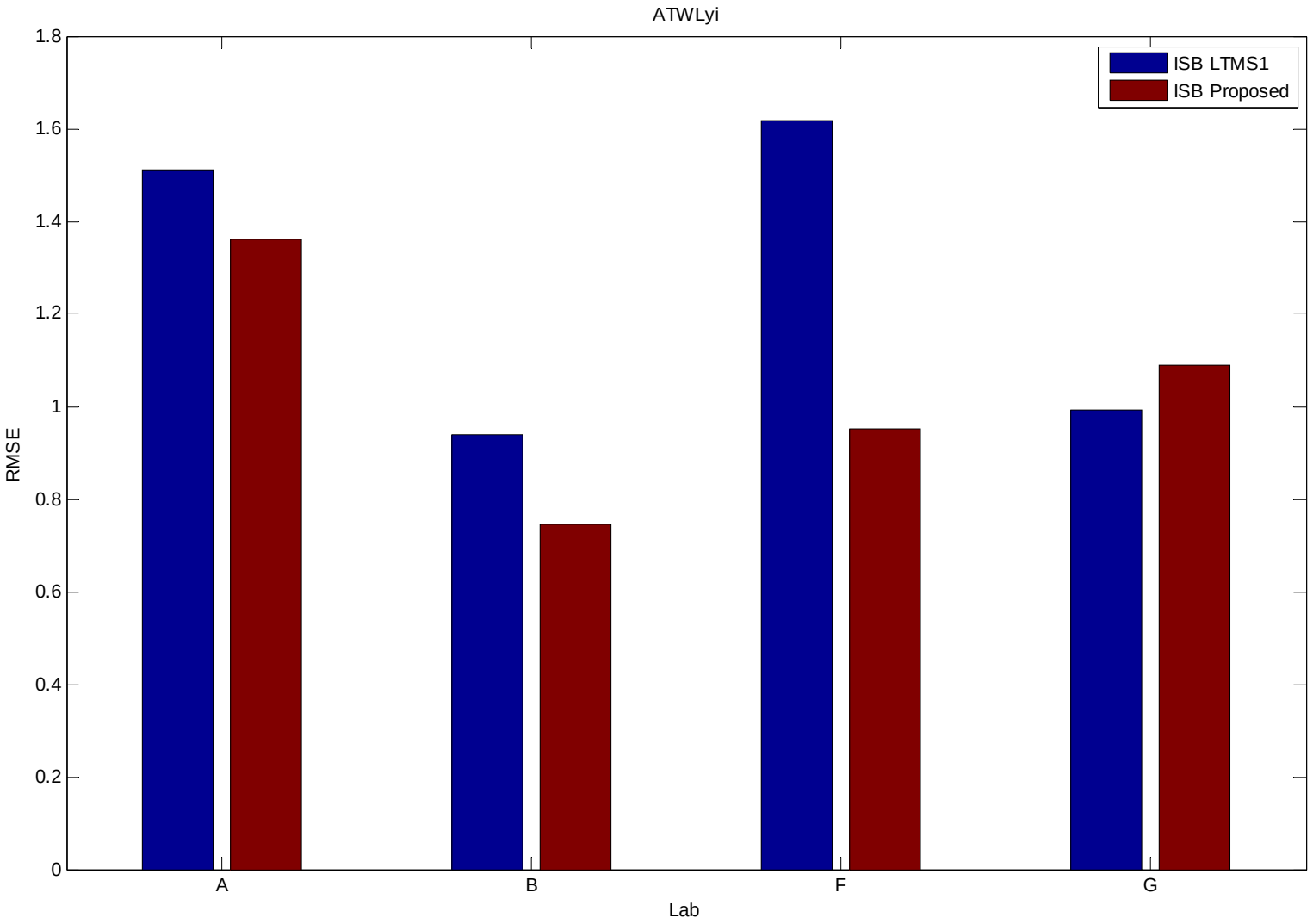


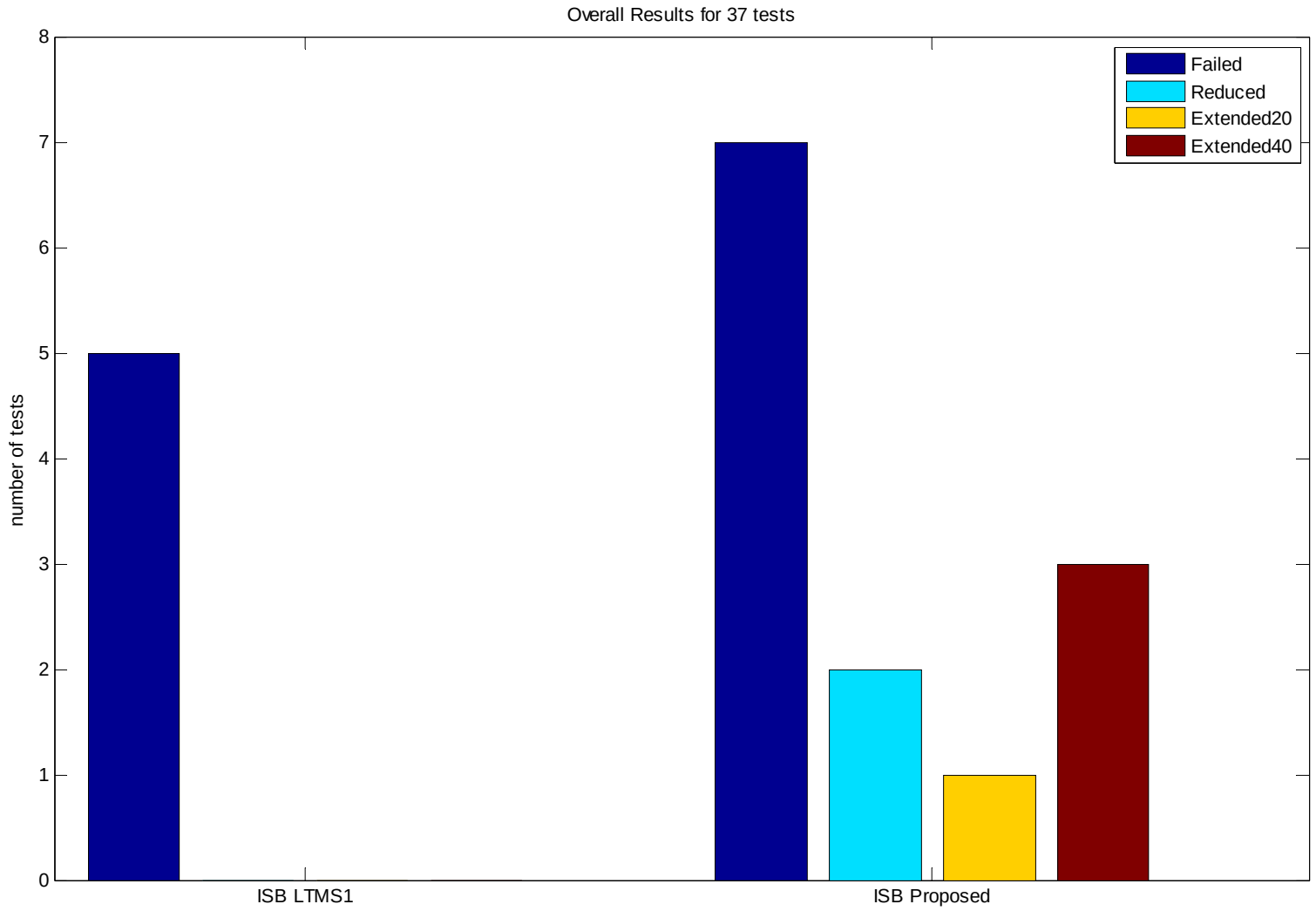
Comparison of LTMS1 and Proposed LTMS2 limits

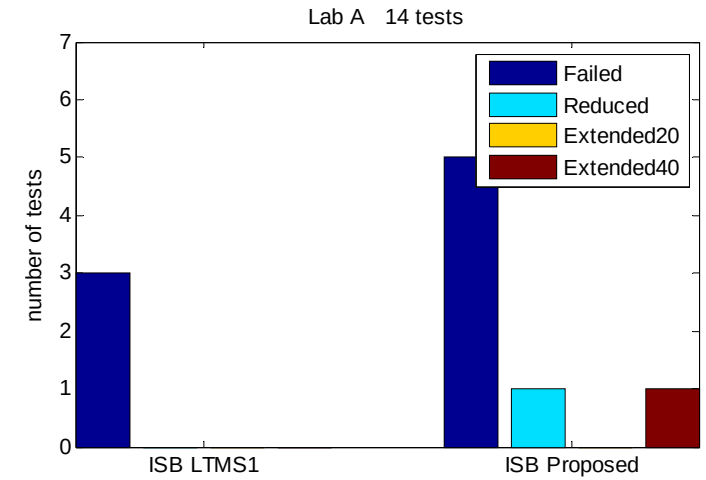
- RMSE (Root Mean Square Errors of severity adjusted reference oil results)
- Number of unacceptable, reduced, and extended reference periods

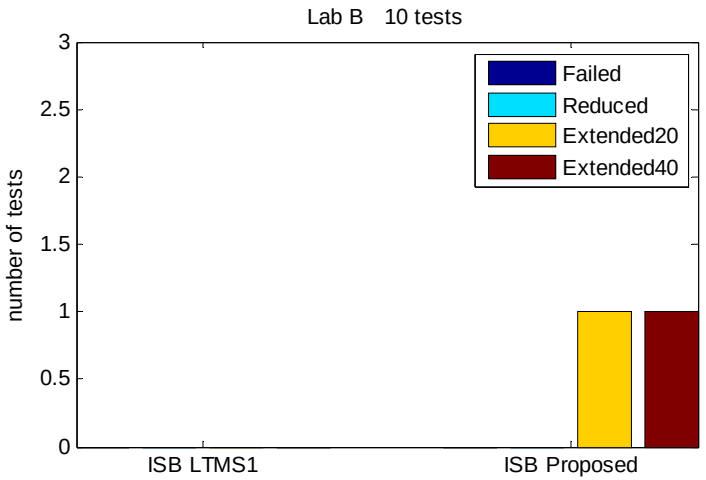

ISB LTMS1
ISB Proposed
RMSE
1.4
1.2
1
0.8
0.6
0.4
0.2
0
ACSWyi
ATWLyi

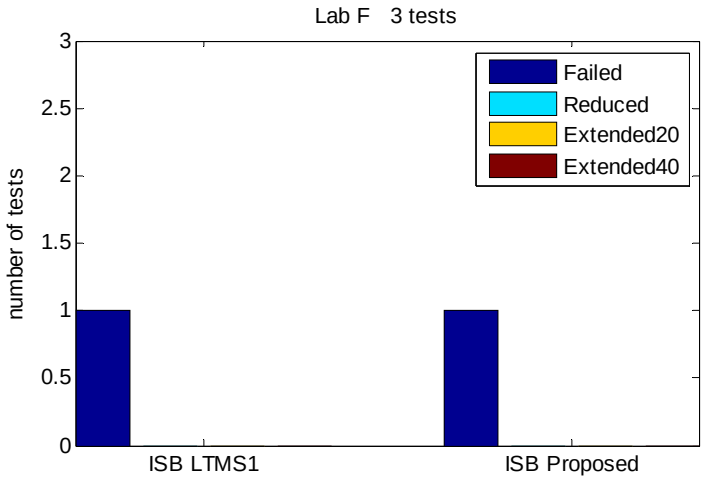

ACSWyi
ISB LTMS1
ISB Proposed
RMSE
2.5
2
1.5
1
0.5
0
A
B
F
G
Lab

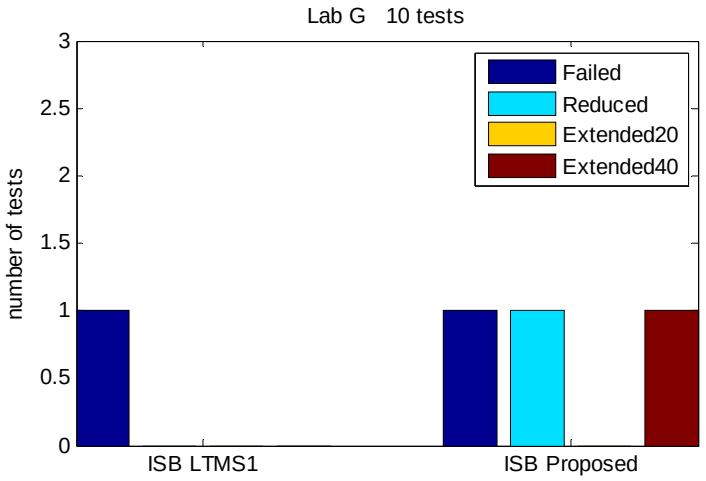

ATWLyi
ISB LTMS1
ISB Proposed
RMSE
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
A
B
F
G
Lab


Overall Results for 37 tests
number of tests
0
1
2
3
4
5
6
7
8
ISB LTMS1
ISB Proposed
Failed
Reduced
Extended20
Extended40


Lab A 14 tests
number of tests
0
1
2
3
4
5
6
7
ISB LTMS1
ISB Proposed
Failed
Reduced
Extended20
Extended40

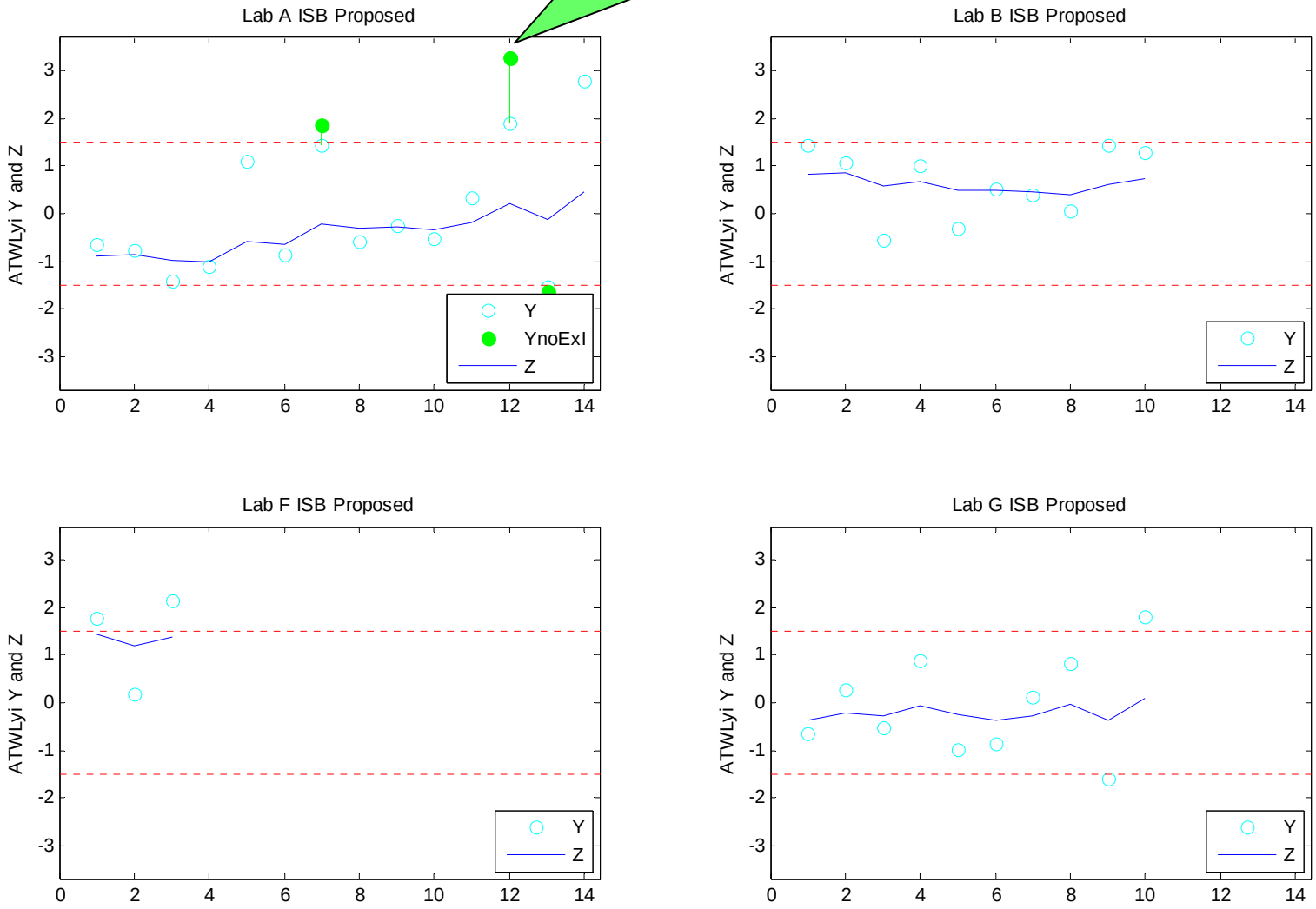

Lab B 10 tests
number of tests
0
0.5
1
1.5
2
2.5
3
ISB LTMS1
ISB Proposed
Failed
Reduced
Extended20
Extended40


Lab F 3 tests
number of tests
0
0.5
1
1.5
2
2.5
3
ISB LTMS1
ISB Proposed
Failed
Reduced
Extended20
Extended40


Lab G 10 tests
number of tests
0
0.5
1
1.5
2
2.5
3
ISB LTMS1
ISB Proposed
Failed
Reduced
Extended20
Extended40

Clarifying Comments

Excessive Influence calculation adjusted Y results from green filled circle to cyan circle.

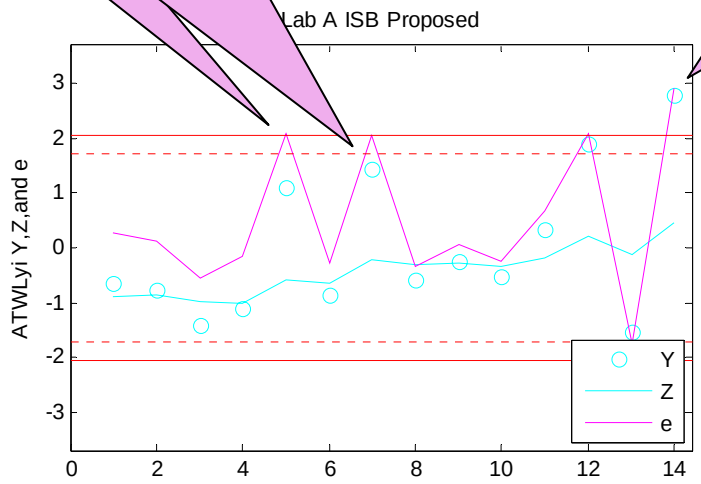


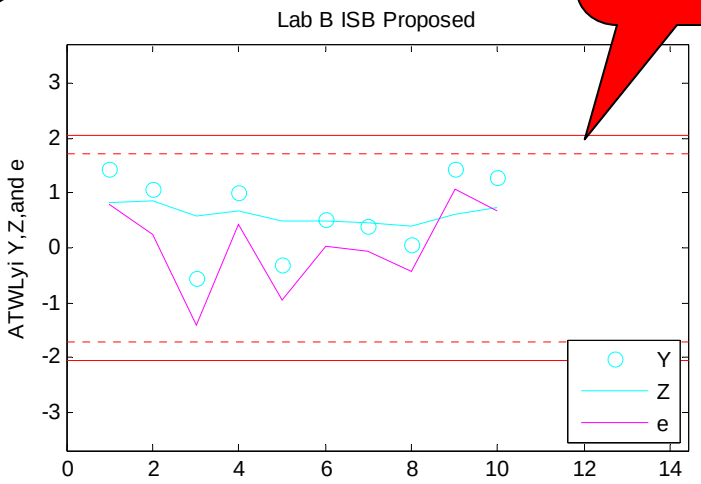
Tapper weight loss severity charts showing Excessive Influence calculation

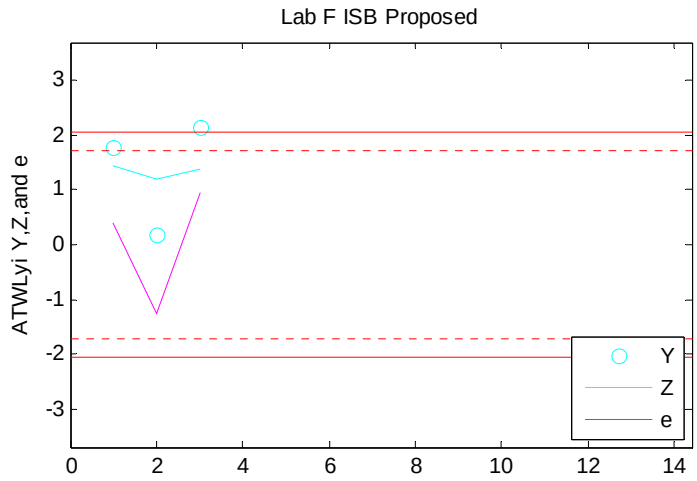
These are examples of results that trigger alarms in LTMS2 but not LTMS1. While their Y results are not excessive, their e values are high (~1.1) because they outlie the lab's Z baseline (~-0.9).

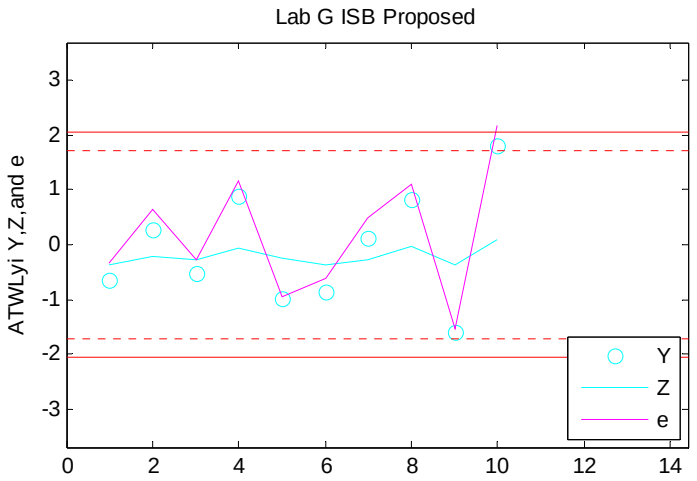
This is an example of a result that would trigger alarm in either LTMS1 and LTMS2. It has a high Y value that exceeds LTMS1 limit. It has a high e value because its result (~2.8) outlies the lab's Z baseline (~0.1).

The dotted line is Level 2 e alarm, and solid line Level 3 e alarm



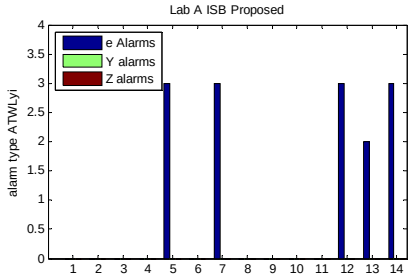


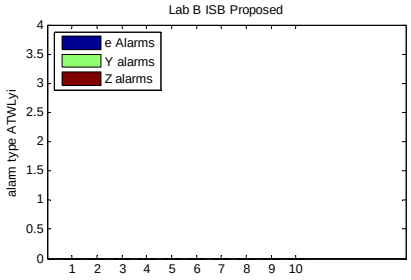


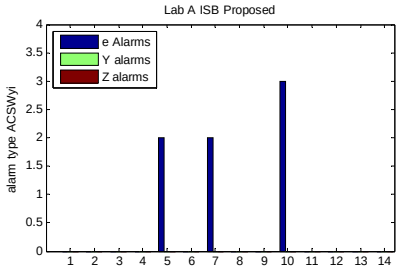


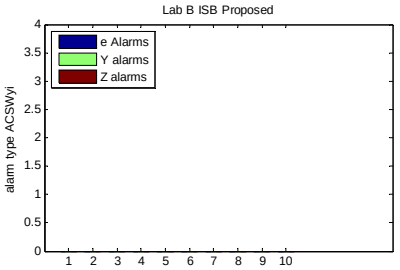
Tapper weight loss precision charts showing e

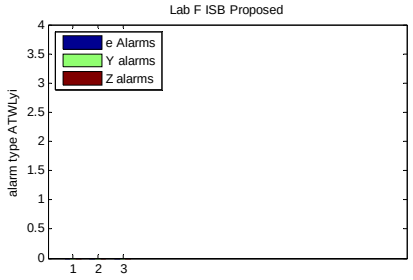
Notice that in LTMS2 study of historical results, all alarms are e alarms. No Z alarms were triggered.

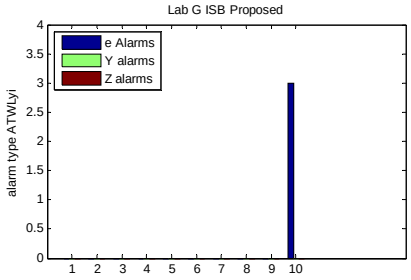


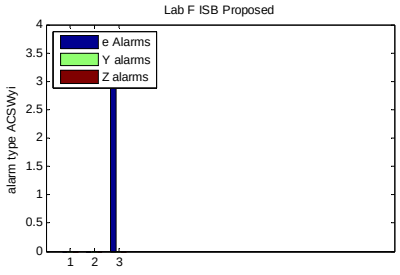


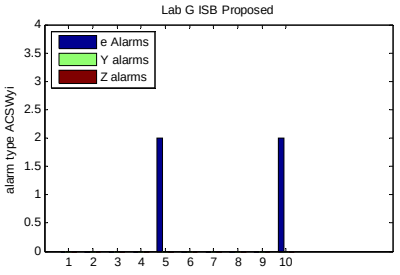












Attachment 8

ISB: lambda: 0.2

Tappet Weight Loss
Default ei:
2.066, 1.734, 1.351
Level 2 Zi: -1.5/+2.0
Level 1 Zi: 0
Ee: 0.5
Ez: 0.5

Cam Wear
Default ei:
2.066, 1.734, 1.351
Level 2 Zi: -1.5/+1.5
Level 1 Zi: 0
Ee: 0.5
Ez: 0.5

Industry
Level 1 Zi: +/-0.653
Level 2 Zi: +/-0.860

Attachment 9

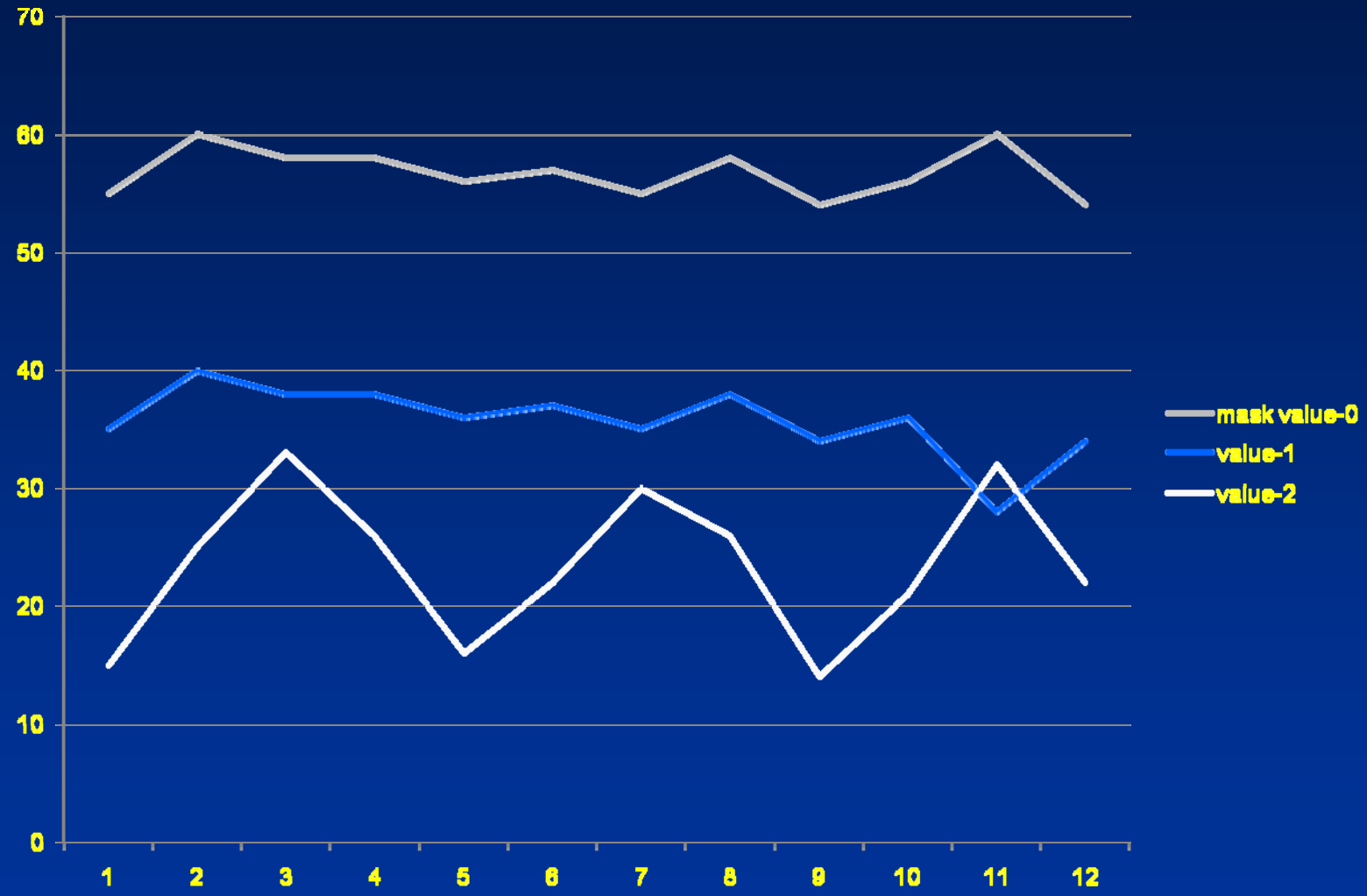
Chevron Phillips Chemical Co.
Specialty Chemicals

Tom Wingfield

Surveillance Panel Meetings

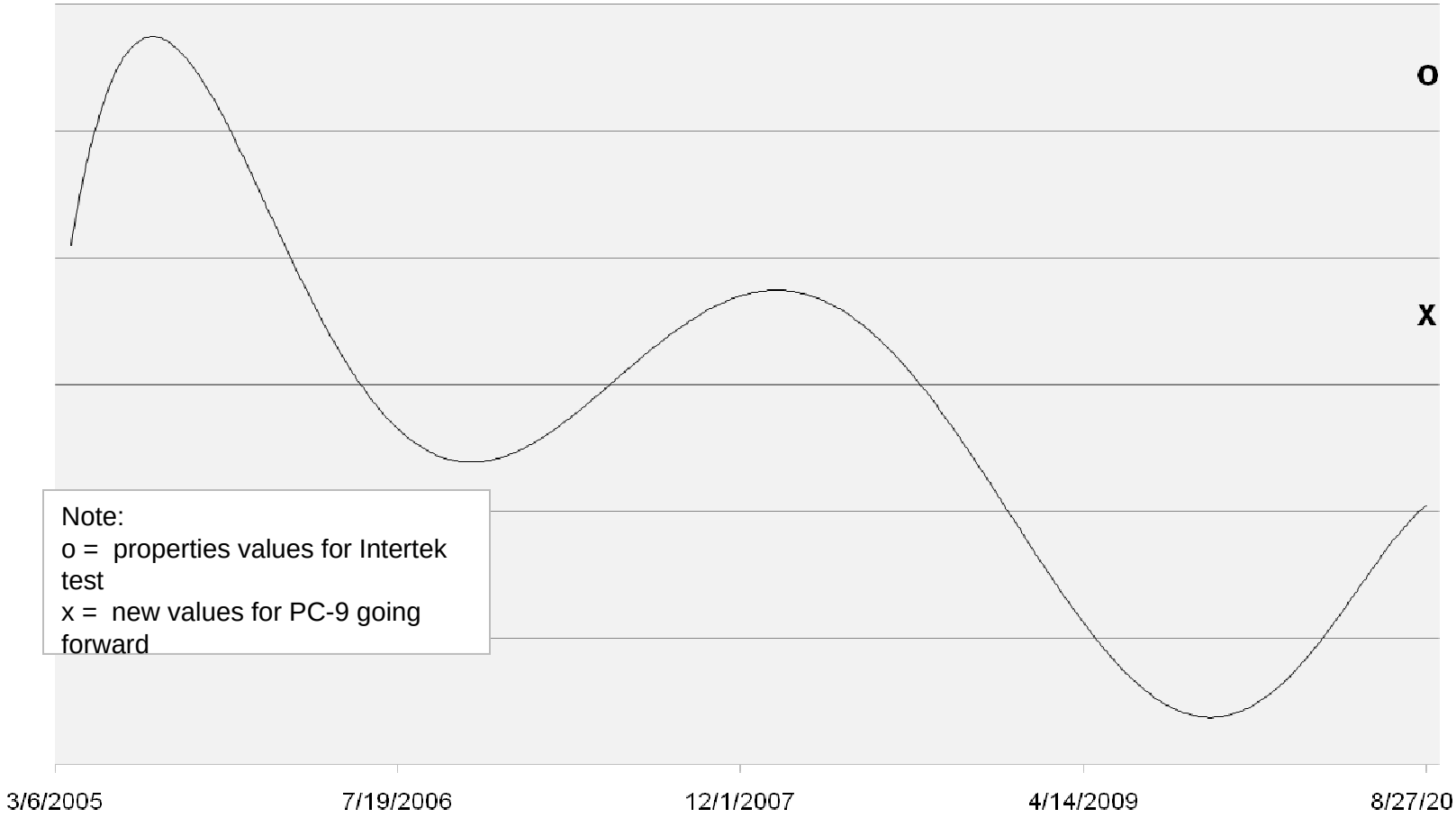
PC-9 Diesel Fuel

EXAMPLE
Masking of Properties Trend



Tom Wingfield
Surveillance Panels
Sept 21-23, 2010

PC-9 Diesel – Properties Trend

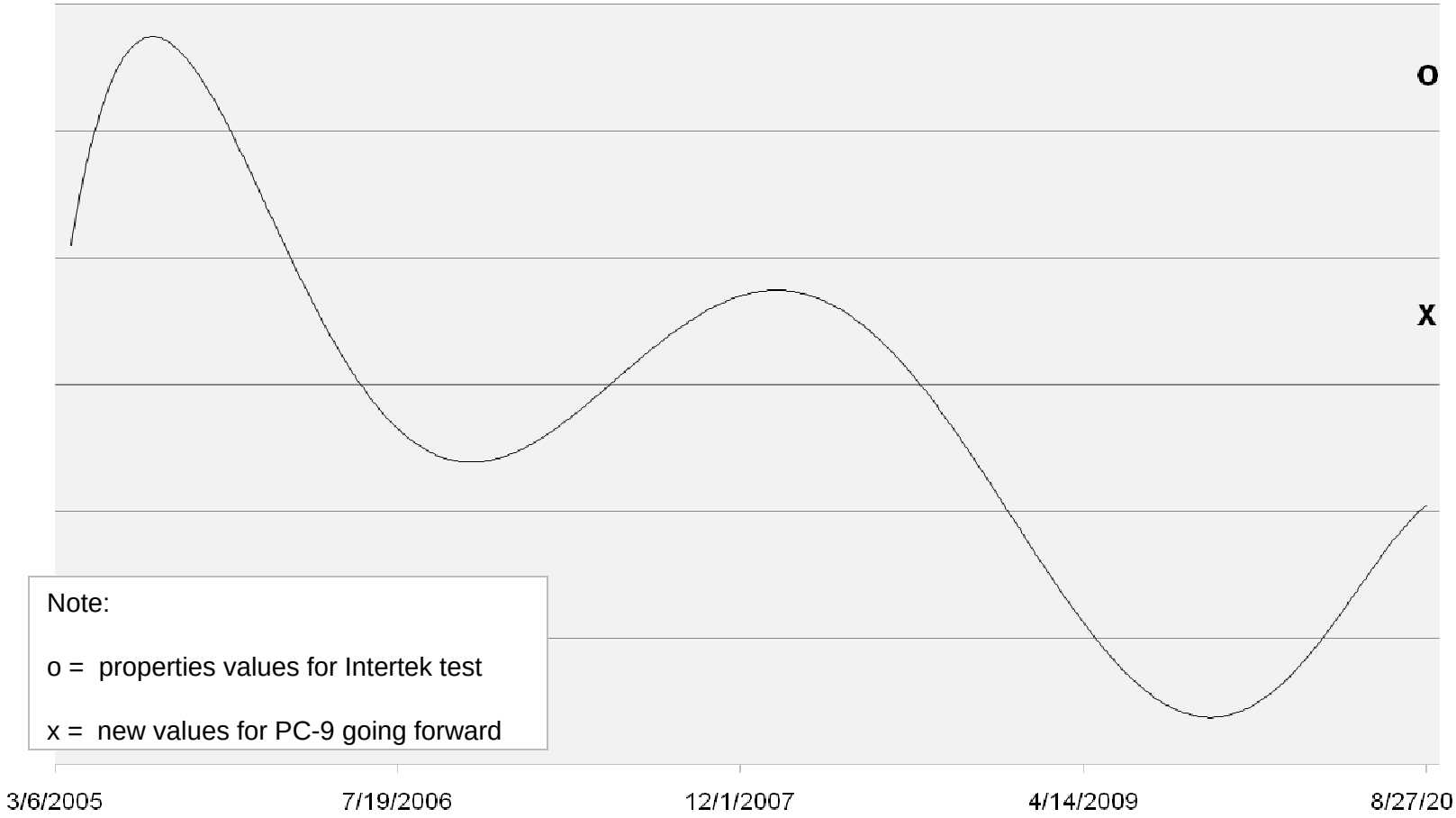


Tom Wingfield
Surveillance Panels
Sept 21-23, 2010

Executive Summary

- For our initial test at Intertek, we turned the knobs to achieve the data point “o”
- With the Intertek test, the primary objective was to assure that the knobs we turned would give a severe result, which it did.
- For the test at Intertek, the resulting PC-9 was *near* specification
- For the PC-9 going forward, we are dialing back the knobs to achieve the data point “x”

PC-9 Diesel – Properties Trend

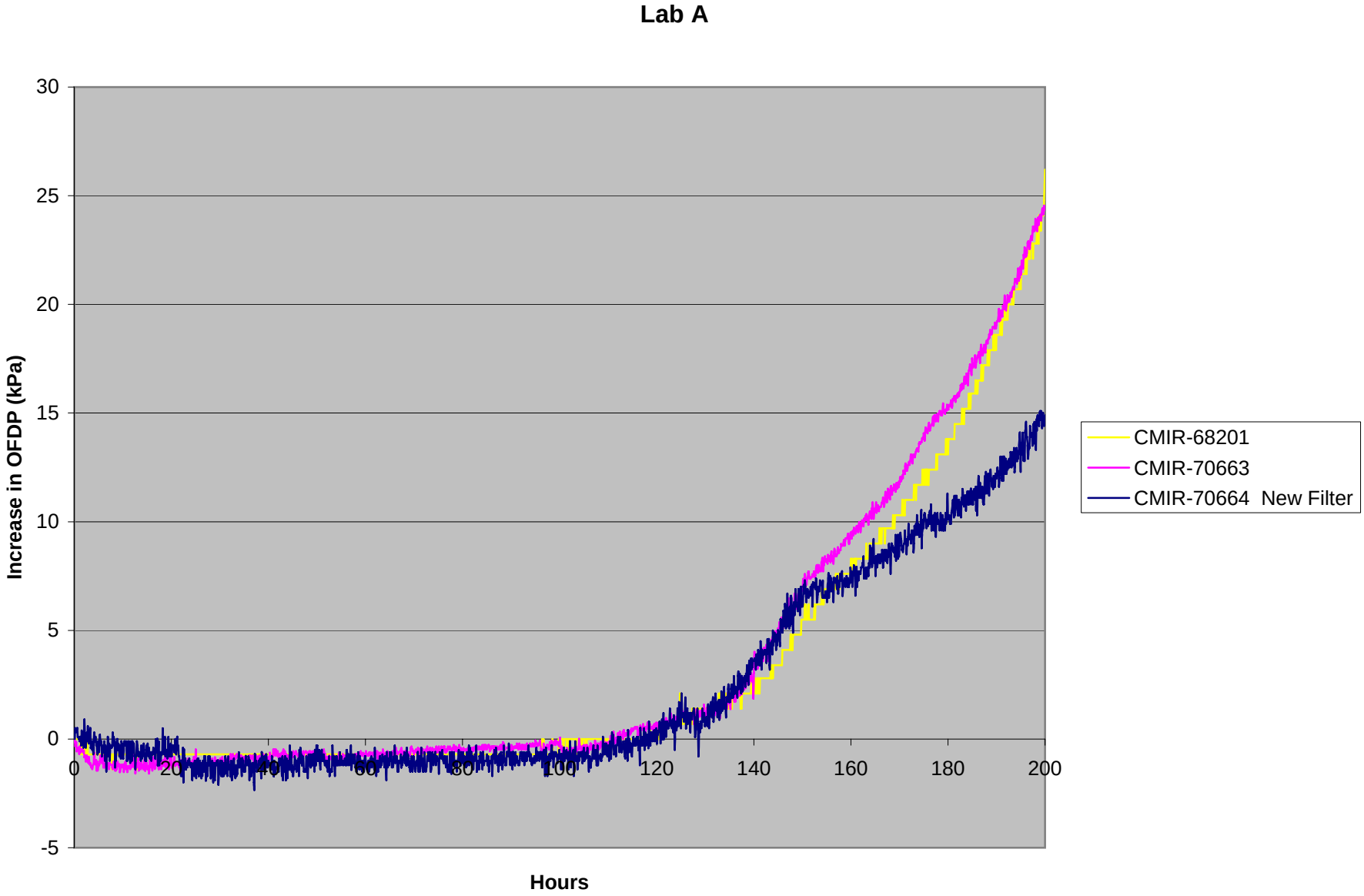


Tom Wingfield
Surveillance Panels
Sept 21-23, 2010

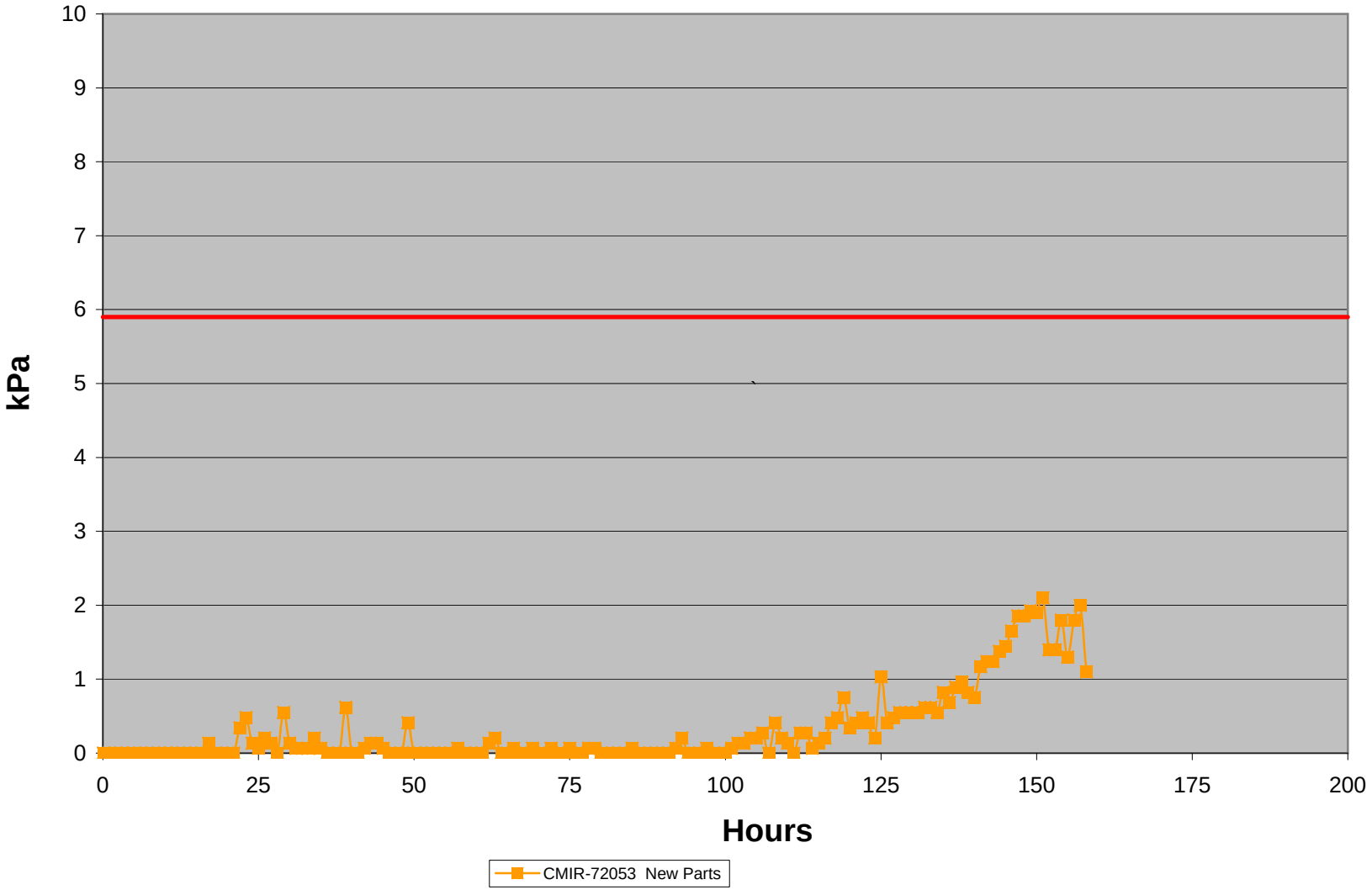
Conclusions

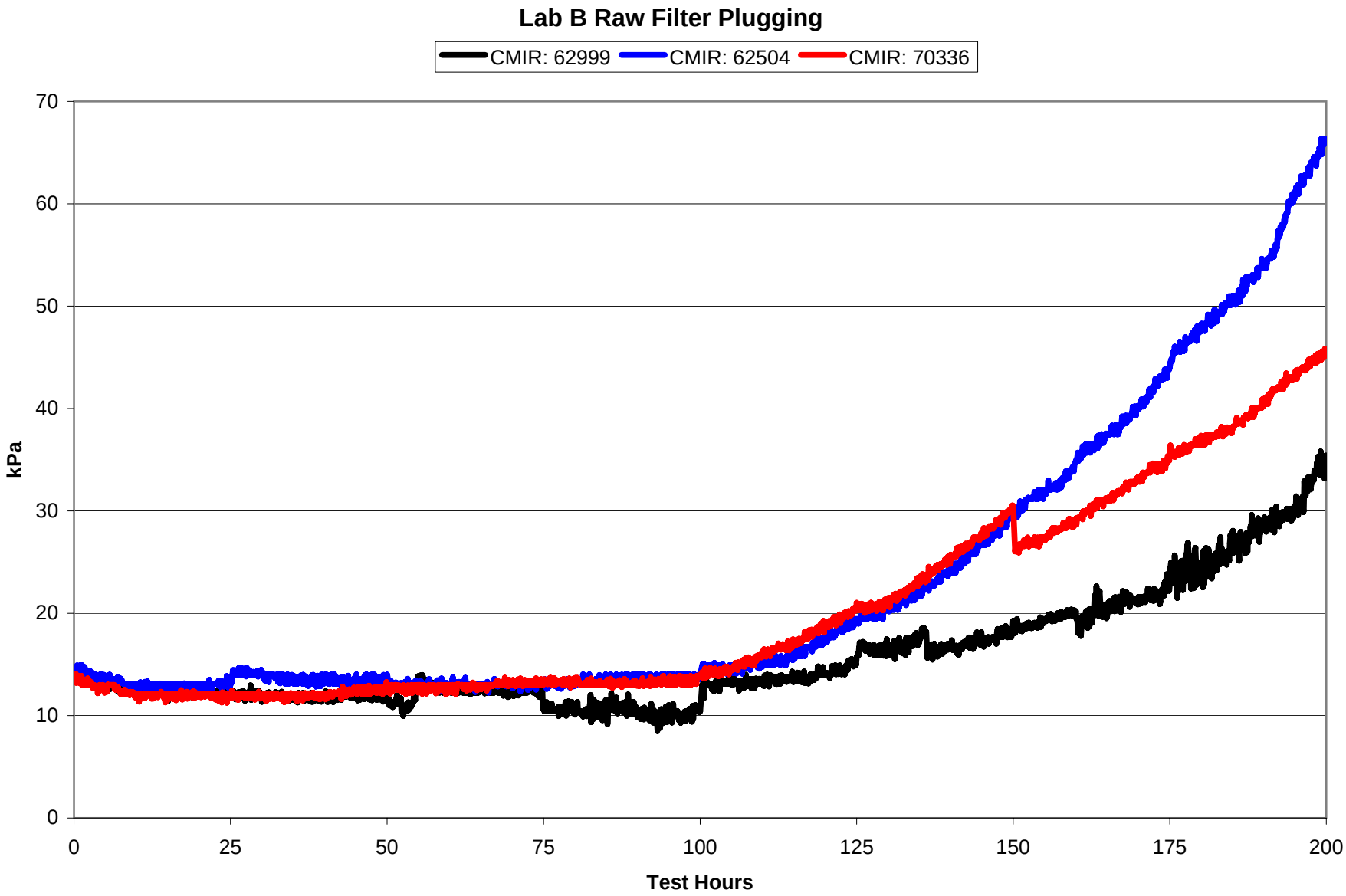
- **PC-9 going forward will be on-spec and still achieve the severity desired for the T-11 test**
- **All of this was necessary because of the changing nature of available refining streams which are tuned to meet the *commercial* fuels market**

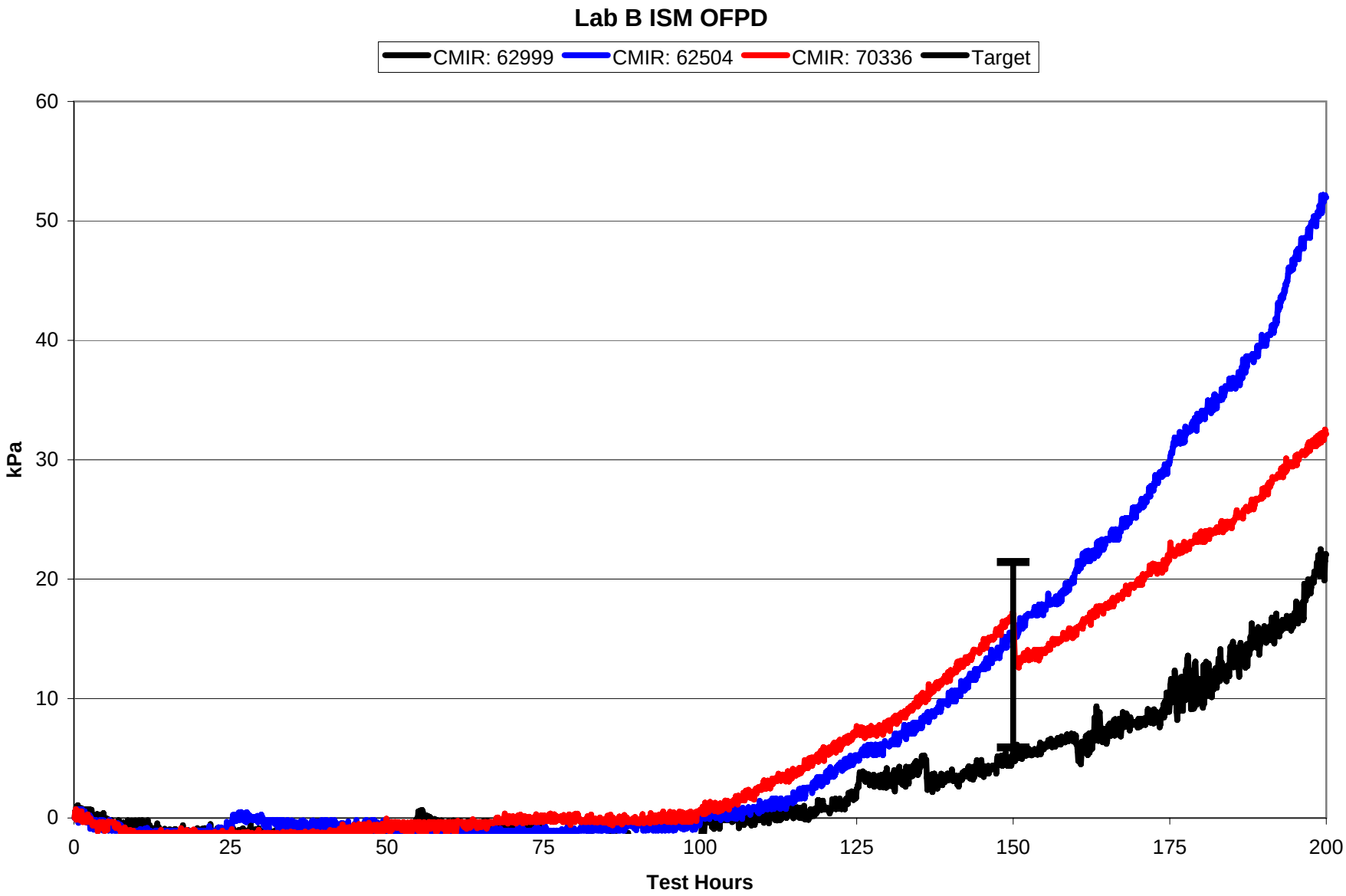
Attachment 10

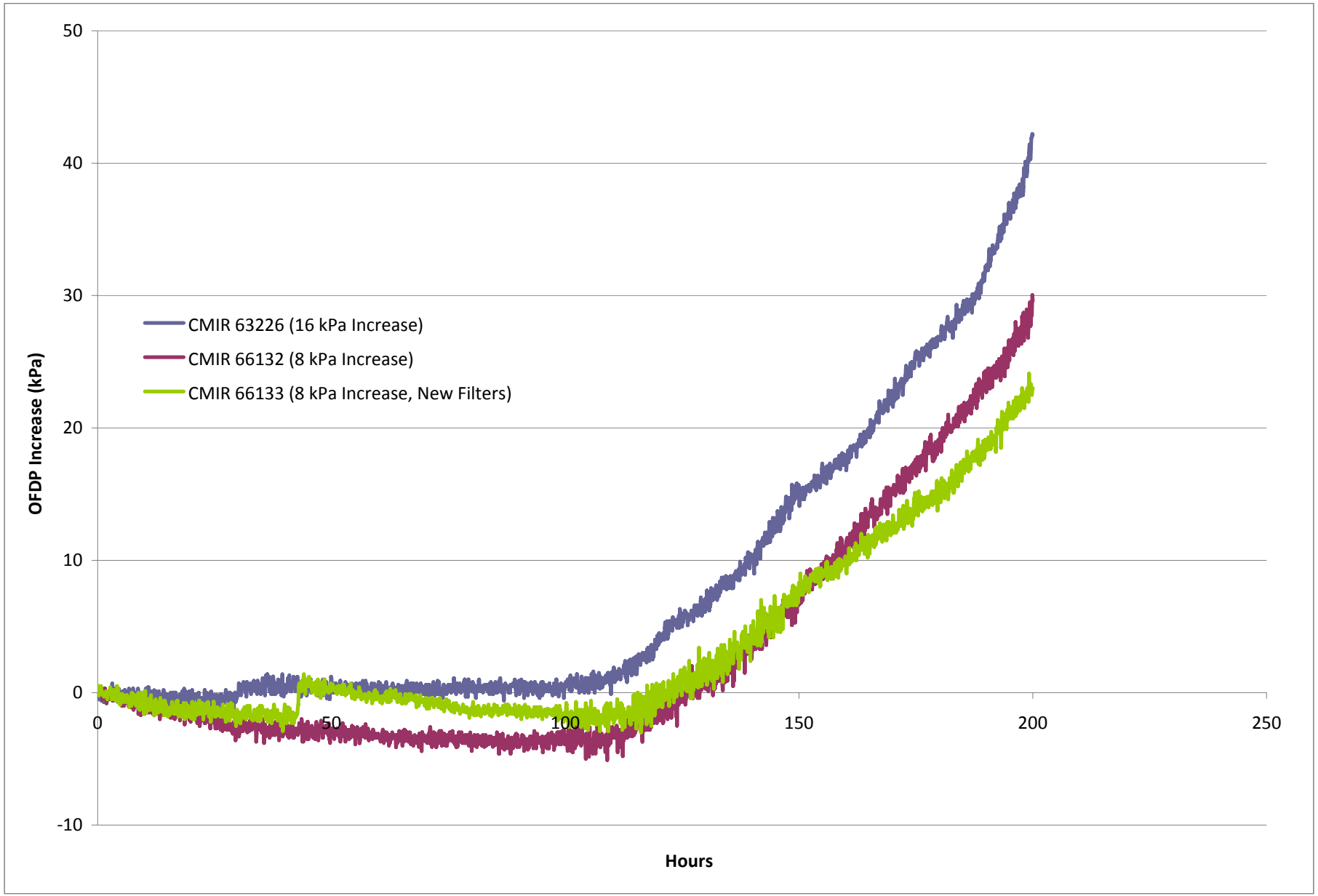

Lab A
Increase in OFDP (kPa)
30
25
20
15
10
5
0
-5
0
20
40
60
80
100
120
140
160
180
200
Hours
CMIR-68201
CMIR-70663
CMIR-70664 New Filter

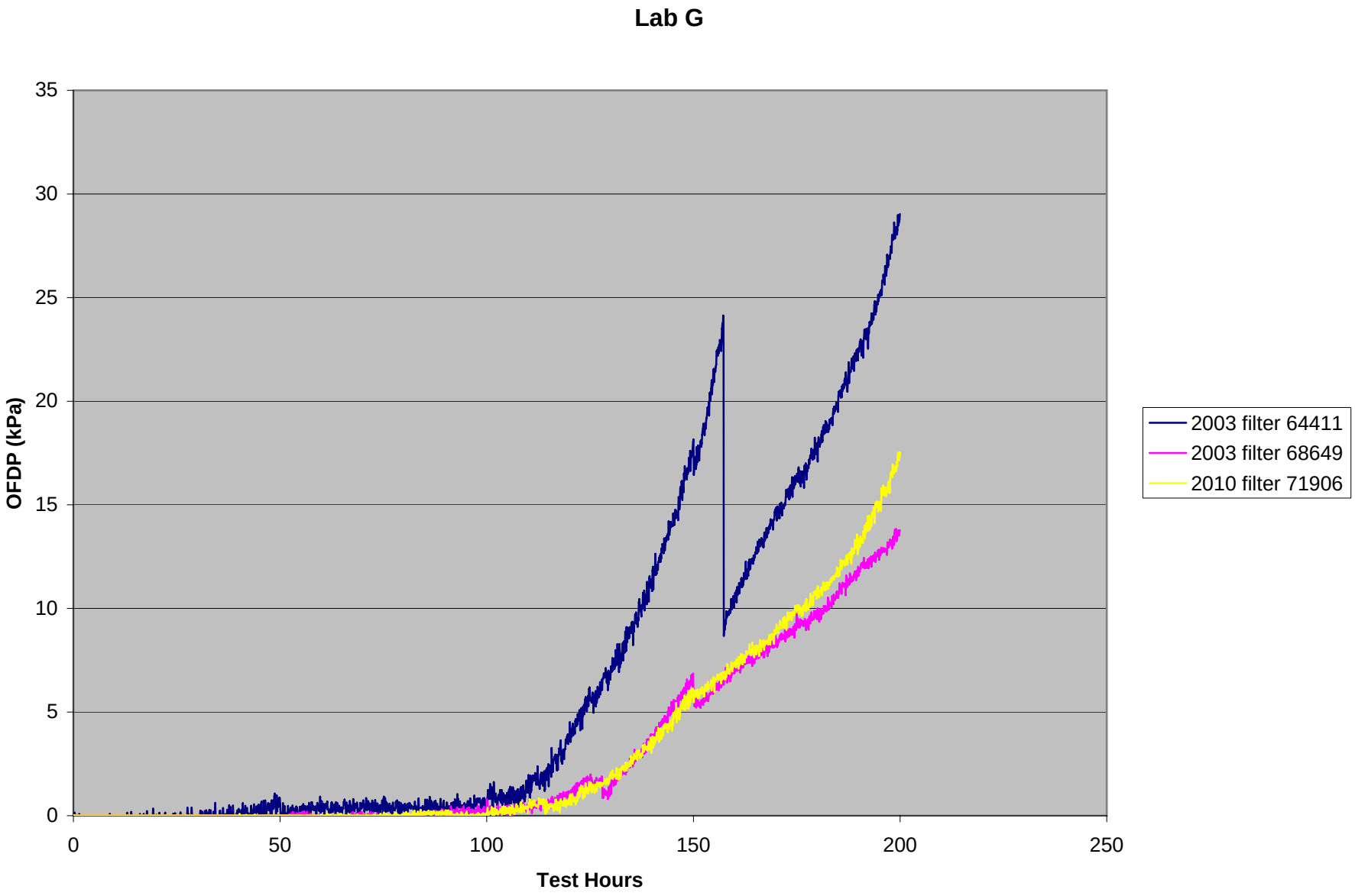
OFDP


10
9
8
7
6
5
4
3
2
1
0
kPa
0
25
50
75
100
125
150
175
200
Hours
CMIR-72053 New Parts

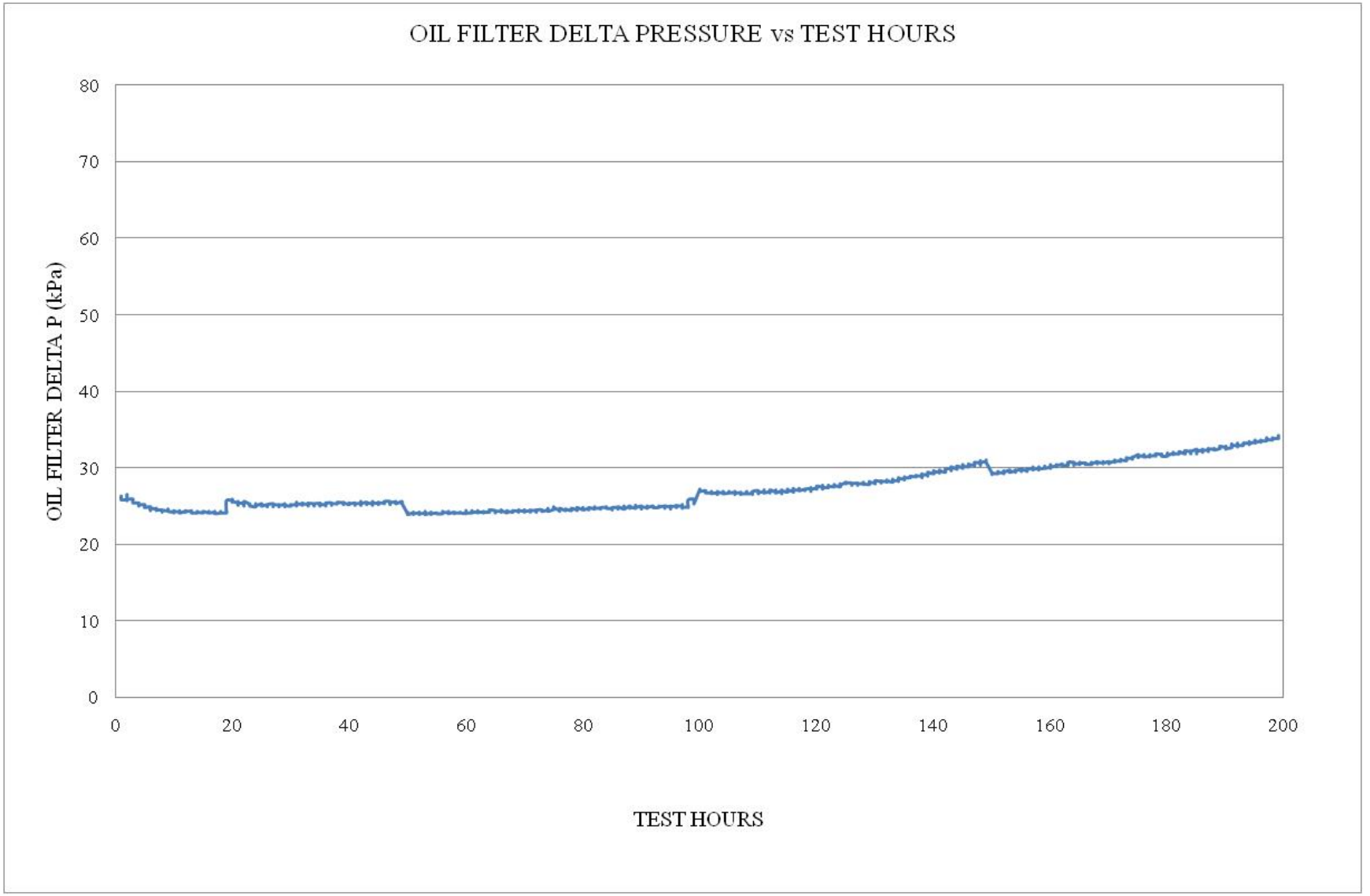

Lab B Raw Filter Plugging
CMIR: 62999
CMIR: 62504
CMIR: 70336
kPa
70
60
50
40
30
20
10
0
0
25
50
75
100
125
150
175
200
Test Hours


Lab B ISM OFPD
CMIR: 62999
CMIR: 62504
CMIR: 70336
Target
60
50
40
30
20
10
0
kPa
0
25
50
75
100
125
150
175
200
Test Hours


50
40
30
20
10
0
-10
0
50
100
150
200
250
OFDP Increase (kPa)
Hours
CMIR 63226 (16 kPa Increase)
CMIR 66132 (8 kPa Increase)
CMIR 66133 (8 kPa Increase, New Filters)


Lab G
35
30
25
20
15
10
5
0
OFDP (kPa)
0
50
100
150
200
250
Test Hours
2003 filter 64411
2003 filter 68649
2010 filter 71906

LAB C


OIL FILTER DELTA PRESSURE vs TEST HOURS
OIL FILTER DELTA P (kPa)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
160
180
200
TEST HOURS